Quantifying the Macroeconomic Effects of Tax Competition: the Brazilian "Fiscal War"

Plinio Dias Bicalho*

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Abstract

This paper studies the role of tax competition among state governments in reducing aggregate public goods provision. To this end, I develop a spatial general equilibrium model with multiple sectors, endogenous state taxes, and firm location choices. Endogenous tax rates allow me to characterize tax competition as a Nash equilibrium among state governments. I estimate the model using novel state-level data on sector-specific tax exemptions in Brazil, and I use bilateral trade flows data and a simulated method of moments procedure to calibrate key model elasticities. My estimates and the theoretical framework jointly indicate that Brazilian tax competition is largely driven by state competition over manufacturing activity, whereas competition over services plays a limited role. Finally, relative to a harmonized tax regime, I find that tax competition reduces public goods provision by 11 percent, providing no aggregate gains in consumption. However, certain states lose tax revenues and consumption if tax competition is fully eliminated.

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1 Introduction

Within a country, decentralized tax systems allow states and municipalities significant autonomy to set their own tax policies. Decentralized tax systems exist to varying degrees across countries. Oftentimes, however, local governments use this decentralized nature to issue tax incentives to attract economic activity to their jurisdictions. Brazil, for instance, stands out as a prominent example. In Brazil, aggressive competition among states for firms is anecdotally widespread. It is widely referred to as the country's own *fiscal war* in public debate and the media.[1] Since fiscal wars may erode state tax revenues and place firms far away from their consumer markets, many have raised concerns about their potential to undermine public goods provision and reduce income.

In this paper, I first develop an analytical model to analyze the central trade-offs inherent in subnational tax competition and derive testable implications. This analytical model highlights the fundamental tension faced by state governments when setting ad-valorem tax rates. Governments in each state prefer a tax rate t_ℓ^{w*} to guarantee a certain level of public goods financing, whereas firms prefer a tax rate t_ℓ^{f*} that maximizes after-tax profits. Under reasonable parametric assumptions, I show that $t_\ell^{f*} < t_\ell^{w*}$. Although state governments would ideally set $t_\ell = t_\ell^{w*}$, interjurisdictional competition for mobile firms induces them to choose rates closer to t_ℓ^{f*}, effectively "poaching" firms from neighboring states. As in a prisoner's dilemma setting, no state can credibly commit to high taxes because each faces strong incentives to undercut the others. I formally characterize this equilibrium and demonstrate that any decentralized tax system with multiple competing jurisdictions is Pareto inefficient.

Building on this framework, I derive two key empirical predictions. First, in equilibrium, more populous states should set higher tax rates on firms. In other words $\text{corr}(t_\ell, L_\ell) > 0$, if t_ℓ and L_ℓ denote effective tax rates and population size, respectively. Second, this relationship holds only when firms are mobile and respond to cross-state differences in taxation. Intuitively, populous states are intrinsically more attractive to firms due to their larger labor markets and therefore need not rely on low taxes to attract economic activity. Conversely, incentives to reduce tax rates arise only when firms can relocate in response to tax differentials. Consistent with these predictions, I find that manufacturing tax rates are strongly positively correlated with state population size. In contrast,

[1] It is also commonly referred to as a "race to the bottom" in the United States and the economics literature.

service-sector tax rates, where firm mobility is limited by the localized nature of production, show no systematic relationship with population size.

I then extend my baseline model to perform quantitative exercises. This quantitative model embeds a canonical local public finance environment in a static, spatial general equilibrium setting. The model features four types of agents — state governments, firms, workers, and capitalists — interacting in a spatial economy with heterogeneous value-added tax rates modeled after the Brazilian economy. Firms choose production location(s) and which markets they will serve, subject to local wages, rents, public goods, marketing costs, and idiosyncratic multivariate Pareto shocks. State governments set tax rates, raise VAT revenues, and receive federal transfers. Workers endogenously select their location based on amenities, local labor markets, public goods, and idiosyncratic preferences. Additionally, profits and rents can flow freely across state borders generating trade imbalances, reflecting portfolio ownership of capitalists. Furthermore, the federal government collects taxes and provides federal tax revenue transfers to state governments. I calibrate this quantitative model to perform a counterfactual exercise and estimate the Nash equilibrium tax rates of the decentralized tax system.

The calibration procedure matches model parameters to key features of the Brazilian data, including state value-added shares, labor value-added shares, state trade deficits, federal tax transfer patterns. I use a gravity-model framework to estimate the elasticities that govern firm and worker mobility across states. I also use a simulated method of moments approach to calibrate parameters related to the government's taxation preferences. I then use hat algebra to calculate both predicted Nash equilibrium state-sector-level tax rates, and the effects of eliminating the fiscal war through imposing a uniform, country-wide tax rate.

The exact hat-algebra exercises highlight key mechanisms of tax competition in the Brazilian context. First, the derived Nash equilibrium reinforces the insight that tax competition is primarily driven by state efforts to attract manufacturing firms. The underlying intuition closely resembles standard optimal-taxation logic, such as in the Ramsey framework: macro-public finance models typically find that governments optimally impose higher taxes on goods with relatively more inelastic demand. In my setting, states, similarly, choose to tax the less mobile sector (services) more strongly, while offering relief to the more mobile sector (manufacturing) in a competitive Nash equilibrium.

Empirically, the model's Nash equilibrium only partially matches the tax rates observed empirically. Nonetheless, I argue that this mismatch is informative about the real-world dynamics of tax competition. As described later in this paper, the Nash equilibrium predicts service sector tax rates in line with observed tax rates. The Nash equilibrium, however, systematically overstates the degree of tax competition in manufacturing. In fact, if states best respond to each other in a static setting, manufacturing tax rates should be close to zero in all Brazilian states. This discrepancy reveals that a static game theory model does not allow for sufficient scope for cooperation among governments. In this paper, I argue that this discrepancy likely reflects, among other features, the static nature of the game considered in this paper, which does not allow for cooperation as much a dynamic game would.

I also employ exact hat algebra to construct an exercise that illustrates the benefits of limiting the extent of tax competition. By curbing tax competition through tax harmonization, substantial gains can be achieved in both aggregate public goods provision and aggregate consumption. I show that Brazil can improve aggregate public goods provision without any loss in aggregate consumption: setting a country-wide VAT rate of 11.9 percent leads to a nationwide public goods provision gain of 11 percent, at no cost to aggregate consumption. Conversely, it is also possible to generate aggregate consumption gains without reducing aggregate public goods provision. Harmonizing the VAT at a lower rate of 10.6 percent yields 1.6 percent gains in aggregate consumption, while leaving aggregate public goods provision unchanged.

I emphasize, however, that tax harmonization can impose significant distributional costs. In particular, certain states may experience considerable consumption losses—and, in extreme cases, revenue losses—due to the restriction on their ability to unilaterally set low business tax rates. In the absence of compensatory mechanisms, these distributional effects may generate substantial regional disparities and political resistance.

Brazil provides an ideal setting for this analysis for three reasons. First, Brazilian states have a long history of aggressive tax competition. In the Brazilian "fiscal war," states use VAT incentives to attract firms from one another.[2] Second, the country underperforms on a range of public goods provision indicators even relative to similar developing countries (Mendes (2014)) which makes public expenditure a key aspect for the country's development. Only 65 percent of households are connected to a sewerage system (Census 2022), and public primary education remains weak, with

[2]See, e.g., De Mello (2008), da Costa Campos et al. (2015), and Ferreira et al. (2005).

just 27 percent of students achieving basic mathematics proficiency (PISA 2022). Third, Brazil's transparency laws require states to publicly report the value of tax incentives granted, allowing for the construction of a novel, comprehensive panel of state-sector-level effective tax rates.

Data on state-level tax expenditures are publicly reported by Brazilian states, detailing the amount of tax revenue entitlements forgone through sector-specific tax incentives each year. I compile and categorize these reports to construct a measure of effective tax rates at the sectoral level for each state in Brazil in 2023.

Analysis of the constructed panel reveals that, on paper, Brazilian states forgo approximately 31 percent of VAT entitlements through tax incentives, amounting to US$44.66 billion in 2023. This figure represents about 25 percent of total state tax revenue entitlements, net of federal transfers. The state of Amazonas illustrates the intensity of such incentives: in 2023, it waived US$3.27 billion (roughly R$ 16.36 billion) in VAT revenues—equivalent to 53 percent of its total VAT entitlement.

1.1 Literature Review

This paper is related to several strands of the literature. This paper contributes to the fiscal federalism literature, which studies tax competition among subnational governments and its welfare implications. Oates (1972) and Wilson (1999) provide examples and overviews of this literature. Much of this work has focused on the United States, where competition for mobile resources is frequently described as a "race to the bottom" (e.g., Oates (1993); Wilson (1985), Wilson (1987), Wilson (1991)). Theoretical models in this tradition typically assume cross-state symmetry and representative firms for tractability, but rarely provide empirical assessments and have not provided counterfactual assessments of the aggregate costs of tax competition. In contrast, this paper quantifies the fiscal and welfare impacts of tax competition using a calibrated model and administrative data from Brazil.

On the theoretical front, a growing literature develops models with mobile firms (e.g., Kleinman (2022); Castro-Vincenzi (2023)). The modeling of tax competition across governments is also explored in Ossa (2011), Ossa (2012), and Ossa (2014), although these studies focus on international settings and trade tariffs. Recent research has further examined the effects of firm taxation on various economic outcomes (see, for example, Suárez Serrato and Zidar (2017); Nallareddy et al. (2018); Suárez Serrato and Zidar (2023)). This paper relates to these strands by analyzing tax competition and its costs in a spatial context.

This paper also relates to seminal work in trade economics by borrowing tools of general equilibrium spatial modeling to estimate the aggregate effects of policy changes. My quantitative model uses, for instance, input-output loops at the sector level Caliendo and Parro (2015), firm selection Melitz (2003), and multiregion production Arkolakis et al. (2018).

Finally, I highlight three recent publications that are most closely related to this work. Fajgelbaum and Gaubert (2020) analyze optimal spatial subsidy policy with an emphasis on workers' spatial allocation, but does not model tax competition. Ferrari and Ossa (2023) demonstrate how states seek to attract firms in order to leverage agglomeration spillovers under different subsidy schemes; in their framework, U.S. state subsidies are found to be more cooperative than non-cooperative across states. Fajgelbaum et al. (2019) is in the intersection of the misallocation and spatial literature. Their analysis focuses on misallocation generated by state-level tax rate dispersion and its welfare implications for the United States. I, on the other hand, extend these frameworks to endogenize tax rates and study the effects of tax competition on public capital provision and aggregate consumption. Furthermore, my main specification considers a vital dimension of tax heterogeneity that is not accounted for in this literature: sectoral heterogeneity. By allowing for state-sector-specific taxation, I argue that this paper sheds light on an important piece of the tax competition puzzle.

Section 2 presents relevant background information and institutional details of tax cuts and the Brazilian tax system. Section 3 introduces the dataset built and empirical facts about the effective tax rates and tax cuts in Brazil. Section 4 develops the analytic model, derives propositions, and testable implications of my theoretical framework. Section 5 presents the quantitative spatial model. Section 6 calibrates my model. Section 7 performs counterfactual exercises. Section 8 concludes.

2 Institutional background and overview of the Brazilian VAT

In Brazil, state governments are responsible for setting the country's main value-added tax (ICMS), which is the primary source of subnational tax revenue. Unlike conventional VAT systems that follow the destination principle, ICMS revenues accrue to the state where goods are produced, rather than where they are consumed. This origin-based structure effectively transforms the ICMS into a production tax, rather than a pure consumption tax, and has led to significant inter-state fiscal competition.

The complexity of the Brazilian tax system is reflected in the determination of ICMS tax rates, which in some cases may vary by product, transaction type, and occasionally by specific buyer and seller characteristics. In practice, Brazilian states have historically imposed higher ICMS rates on relatively inelastic goods such as water, electricity, and oil—often among the highest rates observed across the economy. Despite the intricacy of the statutory framework, appendix A shows that manufacturing and services statutory tax rates can be reasonably approximated as 18 percent for intrastate and 12 percent for interstate transactions.

2.1 Tax cuts

When tax cuts are granted, effective ICMS rates may diverge substantially from statutory rates. In these cases, the statutory rate provides only an upper bound for the average effective tax rate at the state level. Tax cuts can be broadly classified into two types: general and targeted.

General tax cuts are tax reductions available to all firms operating in a particular sector or producing a certain good. These reductions, which often apply to final goods, are typically implemented through federal-state agreements (Convênios ICMS) and tend to yield relatively uniform rates across participating states.

Targeted tax cuts, in contrast, are granted to individual establishments, commonly in manufacturing. States create programs that grant a pre-established tax rate reduction for all firms approved by the state government. These cuts often take the form of tax credits, allowing firms to deduct a percentage of their tax liability. Determining which firms are eligible for such cuts involves both legislative parameters—such as eligible sectors and minimum firm size-and considerable administrative discretion by state agencies. While program design is similar across states, the generosity and prevalence of targeted tax cuts vary widely.

Even though it is economically relevant to understand the political economy and nuances of firm selection into these tax cuts, I abstract from these topics in this research paper to focus on macroeconomic effects, so I use aggregate data on tax revenue collection and tax revenues forgone throughout this paper.

3 Dataset

3.1 *Tax revenues waived*

I build a novel cross-sectional database constructed from official state budget projection documents (Leis de Diretrizes Orçamentárias, LDOs) submitted annually by each of Brazil's 27 states. These documents include a standardized section on tax revenue waivers (*Renúncia Fiscal*), as mandated by federal guidelines, which report projected forgone tax revenue by tax base, tax instrument, and beneficiary sector. While some variation exists in reporting practices across states, the vast majority of LDOs follow a similar structure. The projected tax revenue waivers for a given year t are calculated as the net present value of tax expenditures realized in year $t-2$, updated for expected inflation as documented in the LDOs. Using these projections, effective aggregate ICMS tax revenue waivers were recovered for all 27 states in 2023 across 3 sectors: agriculture, manufacturing, and services. Further details on data aggregation and calculation procedures are provided in the appendix.

This dataset is merged with a second panel, obtained from federal government records compiled by the National Economic Policy Council (CONFAZ), which provides data on state-level VAT collections disaggregated by sector. By combining information on collected revenues, forgone revenues, and statutory rates, it is possible to construct effective tax rate measures for each state-sector-year observation.

3.2 State Trade flows

Another important data source is sectoral interstate trade flows within Brazil. The dataset constructed by Haddad et al. (2017) provides detailed information on trade flows between Brazilian states, disaggregated by sector. Sector-level trade shares from this dataset are used to construct corresponding trade share measures in the present analysis, ensuring consistency with the sectoral classification employed throughout my analysis.

3.3 Other datasets

For calibration, additional data describing state-level economic characteristics—such as gross domestic product, population, and sectoral composition—were obtained from two primary sources:

the Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística-IBGE) and the Institute for Applied Economic Research (Instituto de Pesquisa Econômica Aplicada-IPEA). Further details on the datasets and their usage are presented in the calibration section.

3.4 Descriptive statistics

Table 1: Percent of VAT entitlements forgone

State	$\frac{\text{VAT waived}}{\text{VAT entitled}}$	State	$\frac{\text{VAT waived}}{\text{VAT entitled}}$	State	$\frac{\text{VAT waived}}{\text{VAT entitled}}$
AM	61.37%	TO	34.44%	RN	21.42%
PR	52.12%	SP	29.89%	MG	21.32%
MS	46.47%	AL	29.85%	AP	20.53%
DF	44.67%	CE	28.34%	ES	16.64%
GO	40.48%	PE	27.37%	RS	14.17%
MT	40.22%	AC	26.64%	RO	13.92%
RJ	38.43%	SE	24.06%	PI	13.83%
PB	35.66%	BA	23.96%	PA	12.67%
SC	34.44%	MA	23.18%	RR	1.84%

In Brazil, states levy three main taxes: a value-added tax (ICMS), an annual vehicle tax (IPVA), and an inheritance tax (ITCMD). Owing to its broad base, the ICMS is by far the most important source of state revenue. Therefore, forgoing large percentages of VAT entitlements translates to substantial reductions in total tax entitlements.

The table illustrates the substantial magnitude and heterogeneity of ICMS tax incentives across states. In some years, states forgo over 50 percent of their ICMS entitlements, with substantial heterogeneity in the extent to which states forgo tax revenues. While Rio de Janeiro and São Paulo waive 38.43 and 29.89 percent, respectively, Amazonas relinquishes 61.37 percent, whereas Rio Grande do Sul waives only 14.17 percent.

Finally, there is also substantial heterogeneity in tax rates across sectors. Although some states report forgone revenues disaggregated into over 20 sectors, the absence of a consistent sectoral breakdown across all states forces the analysis to be conducted at a more aggregated level, distinguishing only among agriculture, manufacturing, and services.

Agricultural products are generally subject to very low tax rates, irrespective of state-level incentives. Federal legislation requires states to set low ICMS rates on agricultural goods. By

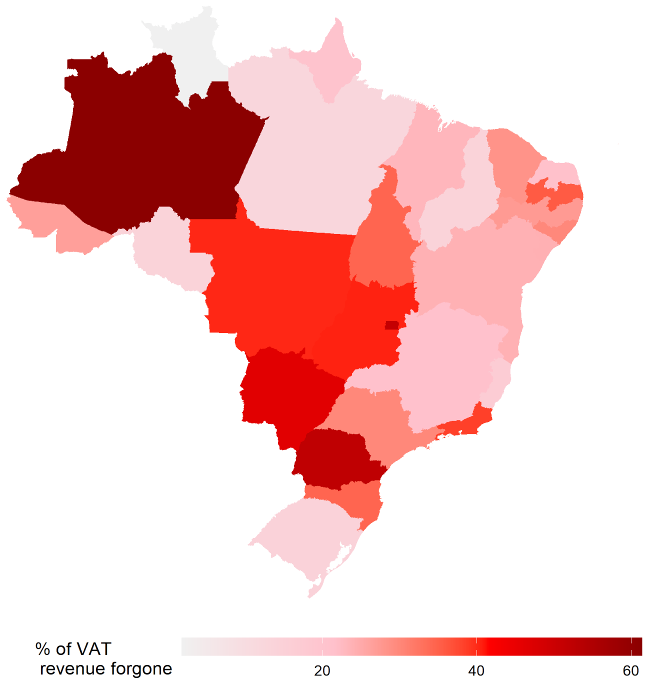


Figure 1: Share of VAT revenues waived through tax exemptions across states.

contrast, manufacturing and services are generally subject to similar statutory rates. Figure 7 in the appendix reports these default statutory rates across states for 2025.

4 Analytic Model

This section presents an analytic model that illustrates the key trade-offs local governments face when setting tax rates in a competitive environment, and it presents testable implications of the proposed model. I generalize the notion of state-level tax competition to a framework in which abstract locations compete for firms and workers. The economy is closed and the environment is static, with $\mathcal{L}$ locations indexed by $\ell \in \{1, \ldots, \mathcal{L}\}$.

A mass of workers, normalized to have total measure one, is distributed across locations. Workers collectively supply $\{L_\ell\}_{\ell=1}^{\mathcal{L}}$ units of labor to local markets and derive utility from private consumption and access to public goods. A mass of firms, also of measure one, chooses locations to maximize profits, which depend on local wages, public goods availability, tax rates, and idiosyncratic shocks. Firms produce a homogeneous good traded without friction in the national market.

Each location is governed by a local government that sets tax rates to maximize per capita household welfare. Higher tax rates increase the provision of public goods, but at the cost of discouraging production and potentially leading firms to move to other locations.

4.1 Households

A continuum of workers, indexed by $h \in [0,1]$, each inelastically supplies one unit of labor. Each worker is assigned to a single location $\ell(h)$ and cannot move across locations. Let $\{L_\ell\}_{\ell=1}^{\mathcal{L}}$ be the mass of workers across all locations so that $\sum_\ell L_\ell = 1$. If N_ℓ^d denotes aggregate labor demand in ℓ, labor market clearing must satisfy:

$$N_\ell^d = L_\ell \tag{1}$$

Each worker h earns the local wage w_ℓ and derives utility from private consumption $c_\ell(h)$ and access to public goods g_ℓ. Consumption must be financed with labor income. Since wages are uniform within a location, consumption is homogeneous across workers. If I let C_ℓ denote aggregate consumption in location ℓ, it must be that:

$$c_\ell(h) = \frac{C_\ell}{L_\ell} = w_\ell. \tag{2}$$

Similarly, individual utility is constant across all households within a location ℓ. Therefore, utility for a household h in ℓ is solely a function of its access to public capital g_ℓ and average household consumption c_ℓ.

4.2 Firms

A continuum of firms, indexed by $i \in [0,1]$, produces a homogeneous final good, with the price normalized to one. Each firm chooses a single location in which to operate and the amount of labor to employ. Firm i's decisions depend on three factors:

1. idiosyncratic firm–location productivity shocks $\{z_\ell^F(i)\}_{\ell=1}^{L}$,
2. location-level productivity shifters $\{\zeta_\ell\}_{\ell=1}^{L}$, and
3. location-level effective tax rates $\{t_\ell^y\}_{\ell=1}^{L}$.

The taxation structure is flexible and will later be restricted to mirror Brazil's system. In particular, the ICMS is modeled as a local revenue tax, consistent with its treatment as a value-added tax accruing to the jurisdiction of production.

Conditional on location ℓ, firm i's production depends on labor input $N_\ell(i)$, local productivity shifters, idiosyncratic shocks, public capital, and local revenue taxes.

A firm locates in ℓ if and only if it attains the highest after-tax profits there. I denote firm i's decision to locate in location ℓ as:

$$i \in \ell \iff \pi_\ell(i) \geq \pi_j(i) \quad \forall j \in \{1, \ldots, L\}. \tag{3}$$

Aggregate variables in location ℓ are denoted by $\{N_\ell^d, N_\ell^s, L_\ell, Y_\ell, \Pi_\ell\}$, corresponding to labor demand, labor supply, households, output, and profits, respectively.

Profits accrue to a foreign capitalist and therefore do not enter local household income. Under a Cobb–Douglas technology with decreasing returns to scale, rebating profits locally to households would yield identical equilibrium outcomes up to a scaling factor α.

4.3 Local Government

The tax system considered is a decentralized tax system. Each location is endowed with a local government. Each local government picks local tax rates to maximize per capita welfare, taking other locations' tax rates as given and subject to a local government's budget constraint:

$$\max_{t_\ell^y} \frac{U_\ell}{L_\ell} \quad \text{s.t.} \quad P^G G_\ell = t_\ell^y \int_{i \in \ell} y_\ell(i)\, di \tag{4}$$

As locations choose tax rates independently to maximize their objective functions, this environment sets up a simultaneous game that locations play. The relevant concept of equilibrium, thus, involves a Nash equilibrium, in which locations best respond to each other by picking tax rates and taking other locations' tax rates as given.

4.4 Decentralized Equilibrium

A general equilibrium with a decentralized tax system in this economy consists of an exogenous spatial distribution of workers $\{L_\ell\}$, an endogenous distribution of firms $\{M_\ell\}_{\ell=1}^L$, aggregate quantities $\{Y_\ell, C_\ell, G_\ell\}_{\ell=1}^L$, wages and local tax rates $\{w_\ell, t_\ell^y\}_{\ell=1}^L$, consumption prices, so that:

1. Labor market clears in each location as in (1)
2. Consumers' budget constraint holds for every consumer, as in (2)
3. Firms choose labor employment and their plant location optimally, according to (3)
4. Local governments maximize local per capita welfare and local governments' budget constraint holds, according to (4)
5. Goods market clearing:

$$Y_\ell = C_\ell + \Pi_\ell + G_\ell \tag{5}$$

4.5 Parametric assumptions

The utility function is assumed to be a Cobb-Douglas composite of their private consumption and public goods access:

$$u_\ell(h) = g_\ell^{1-\gamma} c_h^\gamma = \left(\frac{G_\ell}{L_\ell^{\chi_W}}\right)^{1-\gamma} c_h^\gamma \tag{6}$$

Therefore, per capita welfare in a given location ℓ can be easily computed solely as a function of aggregate public goods and aggregate consumption. In this functional form χ_W dictates the extent to which public goods are rivalrous in the eyes of households. Under $\chi_W = 0$, public goods are perfectly non-rivalrous. On the other extreme, $\chi_W = 1$, public goods are perfectly rivalrous.

The production function is also assumed to be Cobb-Douglas, but with decreasing returns to scale on public goods. Firms take in public goods and labor to produce a homogeneous good.

$$y_\ell(i) = \zeta_\ell z_\ell(i) G_\ell^\beta N_\ell(i)^\alpha \tag{7}$$

Firms will also observe a set of firm-location-specific idiosyncratic TFP shocks $\{z_\ell(i)\}_{\ell=1}^L$ and a fixed set of productivity shifters $\{\zeta_\ell\}_{\ell=1}^L$ before making their location choice. I assume $z_\ell(i)$ are i.i.d random variables, so that $z_\ell(i) \sim \text{Fréchet}(1, \theta)$. The properties of the extreme value distribution and Fréchet yield a tractable expression for aggregate productivity across locations. M_ℓ is the share of national production that takes place in location ℓ. Furthermore, I normalize $P_C = P_G = 1$, so that the public good can be interpreted as the same as the final private consumption good.

The parametric assumptions give rise to the main elasticities of the model (see appendix). One particularly important feature is the *cross-regional tax-output elasticity.* In this setup, when a location changes its tax rate, the aggregate output of all other locations responds in exactly the same way. This happens because the Fréchet shocks are assumed to be i.i.d., which forces the elasticity of Y_j with respect to t^y_ℓ to be constant whenever $\ell \neq j$.

4.6 Nash Equilibrium

Under these parametric assumptions, first-order conditions can be manipulated to yield the intuitive marginal cost and marginal benefit interpretation of first-order conditions. The first-order conditions boil down to:

$$\underbrace{\underbrace{(1-\gamma)}_{\substack{\text{Direct utility}\\ \text{effect}}} + \underbrace{\frac{\beta}{1-\beta}}_{\substack{\text{Multiplier}\\ \text{effect}}}}_{\text{MB}} = \underbrace{\underbrace{\gamma\frac{t^y_\ell}{1-t^y_\ell}}_{\substack{\text{Consumption}\\ \text{appropriation effect}}} + \underbrace{\frac{1}{1-\beta}\left(\frac{1-(\alpha+\frac{1}{\theta})}{\alpha+\frac{1}{\theta}-\beta}\right)(1-M_\ell)\left(\frac{t^y_\ell-\beta}{(1-t^y_\ell)}\right)}_{\text{Firm relocation effect}}}_{\text{MC}} \tag{8}$$

All the work that follows uses the following parametric restriction:

$$\beta < \frac{1}{\theta} + \alpha < 1 \tag{9}$$

These inequalities restrict my analysis to realistic scenarios. The first inequality bounds the extent to which public goods can increase firms' productivity. If this inequality were reversed, returns to investment in public goods are so large that locations would gain firms as they increase effective tax rates. The second inequality restricts the average productivity of firms. Under this inequality, firm size is well-defined as labor demand is well-defined. If this inequality were reversed, in each location, firms would be so productive on average that for any finite wage w_ℓ, firms would demand an infinite amount of labor.

Under condition (9), I achieve the following characterizations of equilibria:

Proposition 1. *Under (9), a decentralized equilibrium* ***always exists*** *and* ***is unique****.*

Exploring the equilibrium conditions pinned down by the first-order conditions, I can rank equilibrium tax rates across states based on location parameters $\{L_\ell, \zeta_\ell\}$:

Proposition 2. *Under (9), in any two locations $\ell \neq j$, the following must hold in a decentralized equilibrium:*

$$\zeta_\ell L_\ell^\alpha > \zeta_j L_j^\alpha \iff t_\ell^y > t_j^y \tag{10}$$

as long as firms are mobile across states ($\frac{dM_\ell}{dt_\ell^y} \neq 0$).

In other words, if preferences are held constant, locations that are naturally more attractive to firms will impose greater effective tax rates. Proposition 2 yields two testable implications that will be explored in the next subsection. First, more populous states should, all else equal, set higher effective tax rates. Second, population levels should only be correlated with tax rates if firms are mobile and respond to tax rates.

Moreover, in a decentralized equilibrium, taxes are inefficiently low in equilibrium:

Proposition 3. *Under (9), an efficient allocation can be achieved as a decentralized equilibrium if and only if $L = 1$ (there is only one location).*

Moreover, for any decentralized equilibrium $\{t_k^{dec}\}_k$, there exists $\varepsilon_k > 0$ such that $\{t_k^{dec} + \varepsilon_k\}_k$ yields a Pareto dominant allocation.

When this final proposition is considered, the decentralized setting of taxes across jurisdictions takes the form of a Prisoner's Dilemma. Each region possesses the capacity to attain a welfare-enhancing allocation through coordinated tax policy and canonical Pareto transfers. Yet coordination proves unattainable because each jurisdiction has an incentive to deviate unilaterally by setting a lower effective tax rate. This strategic asymmetry gives leverage to firms, as governments compete to retain mobile production. Consequently, in equilibrium, each jurisdiction's best response to others' tax choices entails a reduction in its own rate, resulting in a downward convergence of equilibrium tax rates. Most importantly, this proposition relies heavily on the ability of the social planner to operate lump-sum transfers to achieve Pareto-dominant outcomes. In general, in the absence of lump-sum transfers Pareto improvements need not exist. The appendix explores several special cases that further illustrates the roles of mobility and asymmetry in this analytic model.

4.7 Testable implications of the model

The propositions derived yield two testable implications of the model. Proposition 2 predicts that, all else equal, jurisdictions with larger populations will tend to set higher tax rates. Larger labor markets make these locations inherently more attractive to firms, thereby increasing local governments' ability to retain firms at higher tax rates in equilibrium. As a result, populous states can sustain higher effective tax rates than less populous regions. However, proposition 2 only holds when firms are mobile across locations. If firms are immobile—so that M_ℓ does not respond to changes in tax rates t_k^y—then tax competition does not arise, and population size should be uncorrelated with observed tax rates.

Table 2 provides empirical support for these predictions. It shows that the most populous states tend to set higher tax rates. However, this pattern holds only for the mobile (manufacturing) sector. Consistent with the model's predictions, the relationship does not apply to services, where -due to the untradable nature of their output- firms are likely less responsive to local tax differences.

Table 2: Correlation between Population and sectoral tax rates across Brazilian states

	log(tax rate in state ℓ and sector s)		
	(1)	(2)	(3)
$\mathbb{1}\{\text{Manufacturing}\}$	-0.652^{***}		-2.789^{***}
	(0.049)		(0.525)
log(Population)		0.067	-0.006
		(0.046)	(0.027)
$\mathbb{1}\{\text{Manufacturing}\}\times\log(\text{Population})$			0.146^{***}
			(0.036)
Observations	54	54	54
R^2	0.767	0.036	0.845

Notes: The constant term is omitted from the table. Bootstrapped standard errors in parentheses, based on 3,000 pairs-bootstrap replications. $\mathbb{1}\{\text{Manufacturing}\}$ equals one for manufacturing firms and zero otherwise. Population is measured as the log of total local population. The sample includes estimated effective tax rates for manufacturing and services across Brazilian states in 2023. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Such a correlation can help explain how, in figure 2, all Brazilian states levy higher tax rates in services relative to manufacturing.

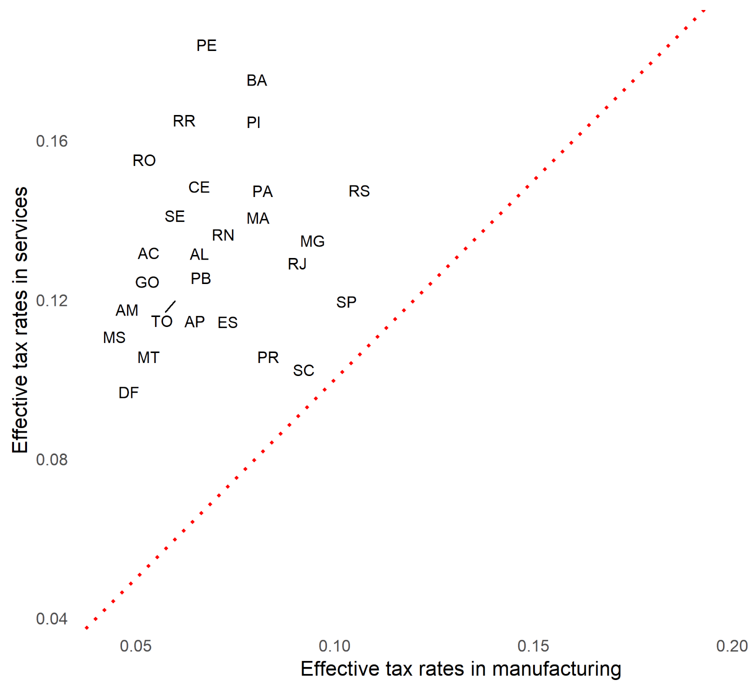


Figure 2: Manufacturing and services effective tax rates across Brazilian states

5 Quantitative Model

I added several features to the baseline model to perform counterfactual exercises. While the core of the baseline model is kept, this section will highlight features to add robustness to my counterfactual analysis. The model is still set in general equilibrium, static and represents a closed economy comprised of $\ell = 1, ..., \mathcal{L}$ locations.

5.1 Households

A mass of measure one of households $i \in [0, 1]$ supplies labor and chooses a residential location. Each household i simultaneously selects its location and labor supply in order to maximize utility $\widetilde{u}$. The utility of household i residing in location ℓ is given by

$$\widetilde{u}_\ell(i) = \zeta_\ell^u \, z_\ell^u(i) \, u_\ell(i) \, d_\ell\left(h_\ell(i)\right). \tag{11}$$

The term ζ_ℓ^u is a location-specific utility shifter, capturing the amenity value of residing in ℓ. The second component, $z_\ell^u(i)$, represents an idiosyncratic preference shock, allowing for household-specific heterogeneity in location choice. The third component, $u_\ell(i)$, reflects systematic utility from objective location characteristics. Namely, $u_\ell(i)$ depends on household i's access to public capital $g_\ell(i)$ and private consumption $c_\ell(i)$. Finally, $d_\ell(h_\ell(i))$ captures the disutility from supplying labor.

Following Fajgelbaum et al. (2019), I parameterize the disutility of labor and the objective consumption–public capital aggregator as

$$d_\ell\left(h_\ell(i)\right) = \exp\left(-\alpha_\ell^W \, \frac{h_\ell(i)^{\,1+1/\eta}}{1+1/\eta}\right), \tag{12}$$

$$u_\ell(i) = \left(\frac{G_\ell}{L_\ell^{\chi_w}}\right)^{\gamma_\ell} c_\ell(i)^{\,1-\gamma_\ell}. \tag{13}$$

The additive separability of the formulation of labor disutility implies that equilibrium hours worked are constant within regions. The specification of public capital access captures the degree of rivalry in the consumption of public goods by households: $\chi_W = 1$ corresponds to perfectly rivalrous provision, whereas $\chi_W = 0$ represents the polar case of non-rivalry. Household consumption is financed entirely out of after-tax labor income,

$$P_\ell^C \, c_\ell(i) = (1 - t_\ell^w) \, w_\ell \, h_\ell(i). \tag{14}$$

Each household is assumed to draw a vector of shocks $\{z_\ell^W(i)\}_{\ell=1}^L$ from a standard Fréchet distribution, and choose to reside in the location that maximizes its utility.

$$\Pr(z_\ell^u(i) < Z) = \exp\left(-Z^{-\theta^u}\right). \tag{15}$$

5.2 Capital Owners

Each location ℓ is endowed with a mass of capitalists who receive the non-labor income in the economy. Capitalists are assumed to be immobile and to have measure zero. This measure-zero assumption guarantees that any labor supply decisions by capitalists are inconsequential in the aggregate and that the degree of rivalry in the consumption of public goods is unaffected by their presence.

Capitalists residing in location ℓ hold fractions of regional portfolios $\{\nu_{\ell,k}\}_k$, which entitle them to a share $\nu_{\ell,k}$ of all the rental income and net profits generated in location k. By definition, it must be that $\sum_j \nu_{j,k} = 1$ and $\nu_{j,k} \geq 0$. Although the model and its solution algorithm can accommodate heterogeneity in portfolio ownership $\nu_{\ell,k}$ across k, I assume that portfolio shares are constant across locations so that $\nu_{\ell,k} = \nu_\ell$. This restriction allows portfolio ownership rates to be calibrated such that net profit and rental flows generate the trade imbalances across states observed in the data.

5.3 Firms

A continuum of goods indexed by $\omega^s \in \Omega^s$ is available in the economy. Each good ω^s is produced by a single firm operating under monopolistic competition within sector $s = 1, \ldots, S$. For simplicity, I use the notation ω^s to denote both a variety and its producer.

Firms may operate multiple plants across locations. Conditional on serving a destination market d, the firm chooses the origin location o that maximizes after-tax profits from serving said market and pricing optimally. Finally, conditional on origin location and optimal pricing, the firm decides whether to incur the fixed marketing costs required to serve market d.

On the demand side, each region is endowed with an aggregate goods sector that combines individual varieties ω^s into sectoral composites. These sectoral composites are subsequently aggregated into two higher-level bundles: an intermediate composite used in production and a final composite allocated to private and government consumption.

5.3.1 Differentiated variety goods: Intensive margin of production

Conditional on location choices and abstracting from marketing costs, the firm's profit maximization problem takes a standard Cobb–Douglas form. Each firm ω^s operating in sector s draws a vector of location-specific productivity shocks $\{z_o(\omega^s)\}_{o=1}^L$. Given these draws, a firm located in o and serving destination market d combines this productivity draw $z_o(\omega^s)$, labor $n_{od}(\omega^s)$, and structures/land $h_{od}(\omega^s)$ to produce output $q_{od}(\omega^s)$. Productivity depends on local public capital available the production site G_o and an idiosyncratic productivity realization $z_o(\omega^s)$:

$$q_{od}(\omega^s) = G_o^{\beta^s}\, z_o(\omega^s) \left[\frac{1}{\phi^s} \left(\frac{n_{od}(\omega^s)}{1-\delta^s} \right)^{1-\delta^s} \left(\frac{h_{od}(\omega^s)}{\delta^s} \right)^{\delta^s} \right]^{\phi^s} \left(\frac{i_{od}(\omega^s)}{1-\phi^s} \right)^{1-\phi^s}, \tag{16}$$

where $i^s_{od}(\omega^s)$ denotes intermediate inputs.

When a firm in sector s located in o sells to destination d, it incurs iceberg trade costs τ^s_{od}.

In addition, firms are subject to value-added taxes $t_{od}^{\text{VAT},s}$ and profit taxes $t_o^{\pi,s}$. As shown in the appendix, this structure yields the following generic net profit function for variety ω^s in destination market d:

$$\pi_{od}(\omega^s) = \left(1 - t_o^{\pi,s}\right) \left\{ \left(1 - t_{od}^{\text{VAT},s}\right) p_{od}^s(\omega^s)\, q_{od}^s(\omega^s) - \frac{\tau_{od}^s\, c_{od}^s}{G_o^{\beta^s}\, z_o(\omega^s)}\, q_{od}^s(\omega^s) \right\}. \tag{17}$$

Here, c_{od}^s denotes the marginal cost of producing in origin o to serve destination d. Given the Cobb–Douglas technology, this function takes the form

$$c_{od}^s = \left[(w_o)^{1-\delta^s} (r_o)^{\delta^s}\right]^{\phi^s} \left((1 - t_{od}^{VAT,s}) P_o^{I,s}\right)^{1-\phi^s} \tag{18}$$

where w_o is the wage, r_o is the rental rate of land and structures, and $P_o^{I,s}$ is the intermediate input price index in location o and sector s.

5.3.2 Differentiated variety goods: location and entry choices

Firms choose to establish production in location o to serve market d if and only if the associated after-tax profits are maximal relative to all alternative locations. This formulation departs from the canonical trade-model structure, in which location and outsourcing choices typically emerge from cost-minimization problems. In the present framework, firm ω^s will select its production site according to:

$$o = \text{argmax}_k \;\; \pi_{kd}(\omega^s) \tag{19}$$

where $\pi_{ko}^s(i)$ denotes the after-tax profit of firm i^s producing in k to serve o. This criterion implies that the equilibrium location of production need not coincide with the cost-minimizing allocation. Instead, fiscal incentives may induce firms to tolerate higher marginal costs in exchange for lower tax burdens, thereby maximizing net profitability. Such behavior captures an essential mechanism of tax competition, wherein tax policies distort firms' location choices across space. Under the parametric assumptions stated, pre-marketing costs profits in origin o from serving destination d in sector s can be rewritten as:

$$\pi_{od}(\omega^s) = \frac{1}{\sigma^s}\,(1-t_o^{\pi,s})(1-t_{od}^{\text{VAT},s})\left(\frac{G_o^{\beta^s}\,z_{od}(\omega^s)}{\tau_{od}^s\,c_{od}^s}\right)^{\sigma^s-1}\left(\frac{P_d^s}{\frac{\sigma^s}{\sigma^s-1}}\right)^{\sigma^s-1} X_d^s \tag{20}$$

where X_d^s denotes total expenditure on sector s in destination d, and P_d^s is the corresponding price index for the composite sectoral good. This expression isolates an origin-specific profitability component that governs firms' location and entry decisions:

$$\kappa_{od}(\omega^s) = (1-t_o^{\pi,s})(1-t_{od}^{\text{VAT},s})\left(\frac{G_o^{\beta^s}}{\tau_{od}^s\,c_{od}^s}\right)^{\sigma^s-1}, \tag{21}$$

It follows that the location-choice condition in equation (19) can equivalently be expressed as

$$[z_o^s(\omega^s)]^{\sigma^s-1}\,\kappa_{od}(\omega^s) \;\;\geq\;\; [z_k^s(\omega^s)]^{\sigma^s-1}\,\kappa_{kd}(\omega^s), \quad \forall k\in\{1,\ldots,L\}. \tag{22}$$

Moreover, entry into serving market d is optimal if and only if

$$[z_o^s(\omega^s)]^{\sigma^s-1}\kappa_{od}(\omega^s) \;\;\geq\;\; \left(\frac{\sigma^s w_d F_d}{X_d^s}\right)\left(\frac{\frac{\sigma^s}{\sigma^s-1}}{P_d^s}\right)^{\sigma^s-1} \tag{23}$$

5.4 Sectoral aggregation

Every location is endowed with an aggregation sector that combines differentiated varieties into both intermediate and final goods. At the first stage, varieties are aggregated into sectoral composites according to the CES demand and monopolistic competition structure. Formally, the sectoral good in market d is given by:

$$Q_d^s = \left(\sum_k \int_{\omega^s\in\Omega^s} [q_{ok}(\omega^s)]^{\frac{\sigma^s-1}{\sigma^s}}\; d\omega^s\right)^{\frac{\sigma^s}{\sigma^s-1}}. \tag{24}$$

In the second stage, sectoral goods are aggregated through Cobb–Douglas production functions into intermediate and final composites. For sector s, the intermediate input bundle in location ℓ is defined as

$$I_d^s = \prod_u (Q_d^u)^{\alpha_d^{u,s}}, \tag{25}$$

while the final consumption good in d is defined as

$$Q_d^f = \prod_s (Q_d^s)^{\alpha_d^{s,F}} . \tag{26}$$

5.5 Aggregation

Productivity shocks $\{z_o(\omega^s)\}$ are assumed to follow the Multivariate Pareto (MVP) distribution introduced by Arkolakis et al. (2018). As they demonstrate, the MVP distribution provides a tractable framework for spatial models, as it preserves properties desirable for aggregation while relaxing the standard i.i.d. assumption on firm-level productivity. In particular, it allows productivity shocks to be correlated across locations. Further details on aggregation and derivations are provided in the appendix.

Conditional on entry into market, the probability that a firm serves destination d from origin o is

$$\psi_{od}^s = \frac{[\zeta_o^F]^{\frac{1}{1-\rho^s}} \left[(1-t_o^\pi)(1-t_{od}^{VAT,s})\right]^{\frac{\theta^F}{(1-\rho^F)(\sigma^s-1)}} \left(\frac{\left(\frac{G_o}{M_o^{XF}}\right)^{\beta^s}}{c_o^s \tau_{od}}\right)^{\frac{\theta^F}{1-\rho^F}}}{\sum_k [\zeta_k^F]^{\frac{1}{1-\rho^s}} \left[(1-t_k^\pi)(1-t_{kd}^{VAT,s})\right]^{\frac{\theta^F}{(1-\rho^F)(\sigma^s-1)}} \left(\frac{\left(\frac{G_k}{M_k^{XF}}\right)^{\beta^s}}{c_k^s \tau_{kd}}\right)^{\frac{\theta^F}{1-\rho^F}}}. \tag{27}$$

Furthermore, this structure yields a gravity equation of the form:

$$\lambda_{od}^s = \frac{[\zeta_o^F]^{\frac{1}{1-\rho^s}} \left[(1-t_o^\pi)(1-t_{od}^{VAT,s})\right]^{\frac{\theta^F}{(1-\rho^F)(\sigma^s-1)}-1} \left(\frac{\left(\frac{G_o}{M_o^{XF}}\right)^{\beta^s}}{c_o^s \tau_{od}^s}\right)^{\frac{\theta^F}{1-\rho^F}}}{\sum_k [\zeta_k^F]^{\frac{1}{1-\rho^s}} \left[(1-t_k^\pi)(1-t_{kd}^{VAT,s})\right]^{\frac{\theta^F}{(1-\rho^F)(\sigma^s-1)}-1} \left(\frac{\left(\frac{G_k}{M_k^{XF}}\right)^{\beta^s}}{c_k^s \tau_{kd}^s}\right)^{\frac{\theta^F}{1-\rho^F}}}. \tag{28}$$

Finally, I show in the appendix that under this aggregation structure, profits net of marketing-cost payments can be expressed directly as a function of sales net of profit and value-added taxes.

5.6 Government side

Taxation in the model is designed to reflect the Brazilian fiscal framework. At the state level, governments levy a value-added tax (ICMS), with revenues accruing to the state of production. At the federal level, the government imposes profit taxes (IRPJ and CSLL), labor-income taxes (IRPF), and a federal value-added tax (IPI). Federal tax revenues are allocated partly as transfers to states and partly as federal expenditures. These instruments represent the most prominent sources of tax revenue at the state and federal levels in Brazil.[3] VAT revenues associated with consumption of sectoral good s in d are:

$$TR_d^{s,ST} = \sum_k t_{kd}^{VAT,ST,s} \left(X_{kd}^s - P_k^{I,s} I_{kd}^s \right) \tag{29}$$

Finally, the federal government collects labor income, profit, and federal value-added taxes. Federal tax entitlements in location o will then be denoted:

$$T_o^{\text{FED}} = \left[t_o^y w_o N_o \right] + \left[t_o^\pi \, \Pi_o \right] + \left[\sum_S \sum_d \left[X_{od}^S - P_o^{I,s} I_{od}^s \right] t_{od}^{VAT,FED,S} \right] \tag{30}$$

I assume that the federal government retains only a share ι_o of such entitlements. The remaining fraction, $1 - \iota_o$, of federal tax revenues is rebated to households and spent locally. This adjustment is necessary to account for three main sources of tax avoidance.

First, informality is pervasive in the Brazilian economy: many workers and firms operate outside the formal system, such that statutory tax rates vastly overstate effective tax collection. Second, as in many other countries, Brazil provides legal channels through which smaller firms and lower-income individuals pay reduced taxes relative to their statutory obligations.[4] Third, the federal government deploys tax incentives—such as temporary tax breaks and targeted tax credits—that allow firms in specific sectors to pay below their statutory tax rates.

Given effective federal tax collection, $\sum_k \iota_k T_k^{\text{FED}}$, the federal government allocates a share s of revenues to direct transfers to states, which are subsequently used for the purchase of final goods. The remaining share, $1 - s$, is devoted to federal expenditures on final goods across locations. Transfers and expenditures in location o are given, respectively, by:

[3]The model abstracts from social security and unemployment insurance transfers. PIS and Cofins-federal social contributions designated to finance unemployment insurance and social security programs-are not included.

[4]The two most prominent examples are the so-called "Simples Nacional" and "Lucro Presumido" regimes. The *Simples Nacional* regime, established by Lei Complementar nº 123/2006, unifies and simplifies taxation for micro and small enterprises. The *Lucro Presumido* regime, created by Lei nº 9.249/1995, provides a simplified presumptive-profit system for corporate taxation.

$$T_o^{\text{FED,transf}} = s\,\xi_o^T \sum_k \iota_k T_k^{\text{FED}}, \tag{31}$$

$$T_o^{\text{FED,exp}} = (1-s)\,\xi_o^D \sum_k \iota_k T_k^{\text{FED}}, \tag{32}$$

where $\{\xi_k^T\}_k$ and $\{\xi^D\}_k$ denote empirically consistent distribution rules governing the allocation of federal transfers and expenditures across states.

Public goods in a location o, however, are financed solely by state-level tax revenues:

$$P_d G_d = \sum_s \sum_k d_{kd}^s TR_k^{s,ST} \tag{33}$$

The allocation of VAT revenues $TR_k^{s,ST}$ across locations depends on a distribution rule $\{d_{kd}^s\}_{k,d}$. When revenues accrue to the state of production, one can set $d_{kd}^s = \lambda_{kd}^s$. By contrast, under a conventional VAT structure in which revenues accrue to the location of consumption, this rule is represented by $d_{kd}^s = 1$ if $k = d$ and $d_{kd}^s = 0$ otherwise.

The assumption that public goods depend solely on a state's own tax revenues is motivated by a body of work estimating the effects of intergovernmental transfers and tax revenue changes in Brazilian municipalities. Gadenne (2017), Caselli and Michaels (2013), and Brollo et al. (2013) find that exogenous increases in government grants translate poorly into outcomes associated with greater provision of public goods, whereas increases in local tax revenues are more strongly associated with improvements in such outcomes.

5.7 Equilibrium

I begin by defining income and expenditure. For each region d, let Y_d^{priv} denote private income and Y_d^{pub} public income. Closely related, let X_d^s denote expenditure on sector s:

$$Y_d^{pub} = T_d^{ST} + T_d^{FED,transf} + T_d^{FED,exp}, \tag{34}$$

$$Y_d^{priv} = \nu_d \left[\sum_k \left(r_k H_k + \widetilde{\Pi}_k \right) \right] + \left(1 - t_d^y\right) w_d N_d + (1 - \iota_d) T_d^{FED}, \tag{35}$$

$$X_d^s = \sum_u \sum_k \Big[(1-\phi^u)\Big(1-\tfrac{1}{\sigma^u}\Big)\alpha_d^{s,u}\lambda_{dk}^u X_k^u\Big] + \alpha_d^{s,f}\big(Y_d^{priv}+Y_d^{pub}\big). \tag{36}$$

Next, consider factor-market clearing conditions. Labor is used in production and to cover fixed marketing costs. Hence, in equilibrium:

$$\begin{aligned} w_d N_d = & \sum_s \sum_k \left(1-\frac{1}{\sigma^s}\right)\phi^s(1-\delta_s)(1-t_{dk}^{VAT,s})\lambda_{dk}^s X_k^s \\ & + \sum_s \sum_k \left(\frac{1}{\sigma^s} - \left(1-\frac{1}{\sigma^s}\right)\frac{1}{\theta^s}\right)(1-t_{kd}^{VAT,s})(1-t_d^{\pi})\lambda_{kd}^s X_d^s, \end{aligned} \tag{37}$$

and similarly, the market for land and structures clears:

$$r_d H_d = \sum_s \sum_k \left(1-\frac{1}{\sigma^s}\right)\phi^s\delta_s(1-t_{dk}^s)\lambda_{dk}^s X_k^s. \tag{38}$$

Goods-market clearing requires that net imports equal the trade surplus term Δ_d:

$$\sum_s \sum_k \lambda_{kd}^s X_d^s - \sum_s \sum_k \lambda_{dk}^s X_k^s = \Delta_d. \tag{39}$$

In this model, trade surpluses are endogenously determined by rent and profit transfers, federal transfers, and state VAT transfers. Denoting $\widetilde{\Pi}_k$ as net profits in market k, it follows that:

$$\begin{aligned} \Delta_d = & \nu_d\left[\sum_k \big(r_k H_k + \widetilde{\Pi}_k\big)\right] - \big(r_d H_d + \widetilde{\Pi}_d\big) \\ & + s\xi_d^T \sum_k \iota_k T_k^{FED} + (1-s)\xi_d^D \sum_k \iota_k T_k^{FED} - \iota_d T_d^{FED} \\ & + \sum_s \sum_k d_{dk}^s TR_k^{s,ST} - \sum_s \sum_k t_{dk}^{VAT,st}\big(X_{dk}^s - P_k^{I,s} I_k^S\big). \end{aligned} \tag{40}$$

5.7.1 Equilibrium in relative changes

Rather than solving directly for the equilibrium in levels, I rely on the method formalized by Dekle et al. (2007). This approach, commonly referred to as "hat algebra," expresses counterfactual outcomes as ratios of equilibrium variables relative to their baseline values under changes in the tax schedule $\mathbf{t}'$. By construction, it eliminates the need to recover unobserved level parameters such as productivity levels, state population shifters, or iceberg trade costs. Instead, the computation requires only observable baseline trade shares $\{\lambda_{od}^s\}$, population allocations $\{L_k\}$, and calibrated elasticity and expenditure parameters to determine general-equilibrium effects. The exact equations used for such a counterfactual exercise are detailed in the appendix.

6 Calibration

Several structural parameters must be calibrated in order to conduct the counterfactual exercises. To discipline some of these values, I rely on a log-linearized version of the gravity equation (28), which can be written as:

$$\log(\lambda_{od}^s) = \alpha_o + \alpha_d + \left[\frac{\theta^s}{1-\rho^s}\frac{1}{\sigma^s-1} + \phi^s\frac{\theta^s}{1-\rho^s} - 1\right]\log\left(1 - t_{od}^{VAT,s}\right) - \frac{\theta^s}{1-\rho^s}\log(\tau_{od}^s) + \varepsilon_{od}^s, \quad (41)$$

where α_o and α_d denote origin and destination fixed effects, respectively. The dependent variable, λ_{od}^s, represents bilateral trade shares, taken from Haddad et al. (2017). Iceberg trade costs τ_{od}^s are proxied by standard gravity variables: the weighted average distance between the five most populous cities across any two states o and d and an indicator for whether states o and d share a border. Estimation results are summarized in the table 3.

Table 3: Gravity equation: OLS and PPML estimates by sector

	OLS			PPML		
	Agriculture	Manufacturing	Pooled	Agriculture	Manufacturing	Pooled
$\log(1 - t_{od}^{VAT,s})$	2.539	3.317	3.886	2.833	8.994	7.977
	(1.920)	(3.728)	(3.411)	(3.754)	(6.200)	(4.336)
Clustered SEs	Origin & Dest.	Origin & Dest.	Origin & Dest.	Origin & Dest.	Origin & Dest.	Origin & Dest.
Observations	729	729	729	729	729	729

Notes: All regressions include origin and destination fixed effects, measures of distances between states, intra-state and border dummy variables, with standard errors clustered by origin and destination. $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$.

OLS and PPML point estimates are similar for agriculture. Elasticity estimates are, however, somewhat noisier and greater for manufacturing under the PPML estimation. I rely on the OLS estimates as they are in line with other literature estimates and perform robustness checks under the PPML strategy.

Given the sparse interstate flows in services, I do not use the services specification to identify trade elasticities. Services trade shares across Brazilian states are highly concentrated at the corners $\{0, 1\}$, reflecting intrastate dominance and limited cross–state transactions. This log-linearized specification induces instability from observations with near-zero values.

Given estimates of the value-added share ϕ^s, and the elasticity of substitution σ^s (which also determines markups), the estimated regression allows me to back out the elasticity $\frac{\theta^s}{1-\rho^s}$. This combination of two parameters governs an object analogous to the canonical trade elasticity and thus plays a central role in determining the responsiveness of firm-location to changes in costs or taxes within the model.

Even under the flexible characterization of the "hat algebra" relative equilibrium transition, a set of parameters must be calibrated to perform counterfactual exercises. The table (4) summarizes the strategy to calibrate these key parameters.

Details on the simulated method of moments are provided in the next section. I perform robustness checks on the choices of $\chi_w = \beta^s = 0$ and show that this specification leads to conservative estimates of the aggregate costs of tax competition in Brazil.

6.1 Simulated Method of Moments

Parameters $\{\gamma_\ell\}$ are both an elasticity and a level parameter of my model. It, partially, determines how migration patterns change as a result of changes in wages and public expenditure. Given the small overall migration elasticity ($\theta^u = 1.73$) of the model, $\{\gamma_\ell\}$ has a limited role influencing aggregate variables in equilibrium. The gammas, more importantly, also pin down the level of taxation across states as it represents how much weight state governments place on tax revenues relative to consumption. I therefore, propose a simulated method of moments strategy to pin down the values of $\{\gamma_\ell\}$. These parameter values are chosen so that:

$$\gamma_\ell^* \in \arg\min_{\gamma_\ell} \sum_s \sum_k \lambda_{\ell k}^s (\hat{t}_{\ell k}^s(\gamma_\ell) - t_{\ell k}^{s,obs})^2 \tag{42}$$

Table 4: Calibration of Structural Parameters

Notation	Value	Description	Targeted moment / source
Preferences and mobility			
η	2.84	Frisch elasticity of labor supply	Chetty et al. (2011)
θ^u	1.73	Migration elasticity	Fajgelbaum et al. (2019)
χ_W	0	Public goods rivalry degree to households	—
Technology and shares			
ϕ^{AG}	0.39	Value-added share in agriculture	Value-added share of gross revenues
ϕ^T	0.21	Value-added share in manufacturing	Value-added share of gross revenues
ϕ^{NT}	0.45	Value-added share in services	Value-added share of gross revenues
$1-\delta^{AG}$	0.35	Labor share of value-added in agriculture	Labor to land/structure cost ratio
$1-\delta^T$	0.25	Labor share of value-added in manufacturing	Labor to land/structure cost ratio
$1-\delta^{NT}$	0.48	Labor share of value-added in services	Labor costs to net sales ratio
Trade elasticities			
$\theta^{AG}/(1-\rho^{AG})$	4.92	Trade elasticity (agriculture)	Gravity equation
$\theta^T/(1-\rho^T)$	8.01	Trade elasticity (manuf.)	Gravity equation
$\theta^{NT}/(1-\rho^{NT})$	6.83	Trade elasticity (services)	Freeman et al. (2025)
Shocks and substitution			
ρ^s	0.55	Correlation of MVP shocks	Arkolakis et al. (2018)
σ^s	4	Elasticity of substitution	Head and Mayer (2014)
β^s	0	Marginal effect of public goods on productivity	—
Fiscal and expenditure shares			
$\{\nu_\ell\}$	—	Portfolio ownership share	Trade imbalances across states
$\{\alpha_\ell^{s,u}\}$	—	I/O material cost shares	Expenditure in intermediate goods by sector
$\{\xi_\ell^T\}$	—	Share of federal transfer entitlements	Federal transfers by state, 2002–2023
$\{\xi_\ell^D\}$	—	Share of federal government expenditure	Federal expenditure by state in 2023
$\{\iota_\ell\}$	—	Effective federal tax collection relative to model prediction	Ratio of effective-to-predicted tax revenue in 2018
$\{\gamma_\ell\}$	—	Public goods utility weight	SMM

Notes: Dashes indicate objects calibrated outside the main parameter vector (state-level shares or residuals). Abbreviations: AG = agriculture, T = manufacturing, NT = services, MVP = multi-variate Pareto.

Intuitively, for every state ℓ, γ_ℓ is chosen so that its associated predicted best-response tax rates in that state, $\hat{t}_{\ell k}$, are close to the observed tax rates. There are three important remarks regarding this specification.

First, I set agriculture tax rates exogenously to zero. This choice mirrors federal government policies that push tax collection to virtually zero across Brazilian states.

Second, as statutory interstate tax rates are fixed and statutory intrastate tax rates require several bureaucratic procedures to be altered[5], in the short run states can only change effective tax rates by manipulating tax cut issuance, which generally apply uniformly across destination states[6]. Therefore, I approximate the states' tax choices as the choice of two scalars $\{\alpha^{manuf}, \alpha^{serv}\}$ that shift statutory tax rates. Further details on the implementation of this simulated method of moments are provided in the appendix.

Third, I assume tax setting does not internalize migration patterns. In other words, as state governments choose tax rates, they do not consider how the resulting migration might induce second wave effects on endogenous variables. This specification choice reflects findings in the literature that migration is mild and slow to respond to shocks to local economic activity (see Autor et al. (2013) and Moretti (2011) for more details).

7 Nash Equilibrium Tax Rates and Counterfactual Exercises

I start by showing how my model predicts states would set manufacturing and service tax rates in a Nash equilibrium. Figure 3 shows how observed tax rates compare to Nash equilibrium tax rates across different states. A weighted average is taken of each destination market tax rate, given observed trade shares, in order to retrieve average state-sector tax rates below.

The tax rates in the Nash equilibrium reinforce the theoretic predictions of the analytic model. More mobile sectors can credibly relocate across state boundaries, giving states a strong incentive to lower effective tax rates on manufacturing in order to retain firms from this highly mobile sector. In contrast, service firms face substantial iceberg trade costs, which sharply limit cross-state mobility. As a result, states can set higher tax rates on services without triggering meaningful firm relocation.

These findings closely resemble the classic insights of Ramsey (1927). In the Ramsey framework,

[5] Therefore, statutory tax rates have remained remarkably stable over time.

[6] There are a handful of minor exceptions. More details on these exceptions are provided in the appendix.

optimal taxation requires placing higher taxes on inelastic goods and lower taxes on goods with more elastic demand, since taxing elastic goods generates disproportionately higher distortions. In my setting, the same logic applies: states optimally choose to tax mobile manufacturing firms more lightly, as taxing them heavily would generate larger production losses through firm relocation responses.

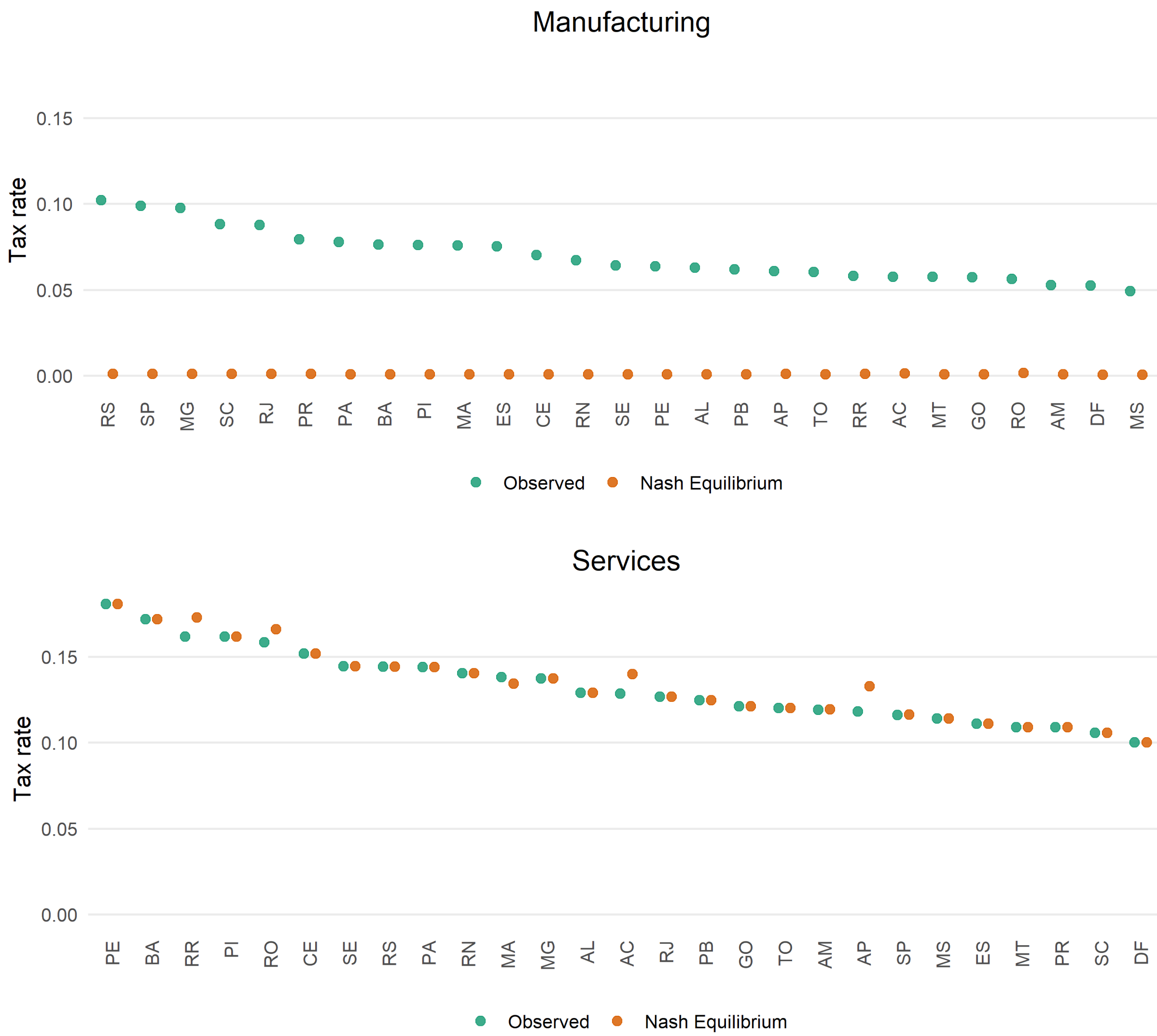


Figure 3: Observed vs. Nash equilibrium tax rates across Brazilian states

In terms of model fit, Figure 3 shows that the proposed static framework closely matches observed effective tax rates in the service sector.

In contrast, the predicted tax rates for manufacturing considerably overstate the degree of tax competition observed empirically. In Nash equilibrium, states in Brazil would tax manufacturing at rates close to zero. In reality, while effective tax rates in manufacturing are substantially lower than in services, no state imposes effective tax rates lower than 4% on manufacturing. I claim that this discrepancy is informative as it showcases the current static game theory framework does not allow for sufficient cooperation across states.

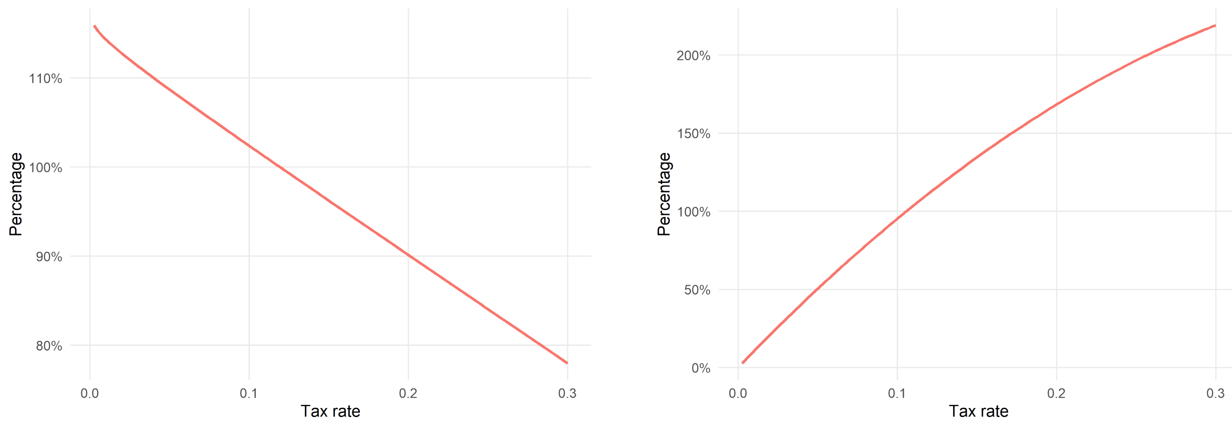
I argue that the lack of cooperation likely reflects the static nature of the game proposed: without a future horizon, states have no incentive to maintain cooperative behavior and therefore optimally undercut one another fully in the mobile sector. In a classic insight of the canonical Prisoner's Dilemma, introducing a future horizon in a dynamic setting opens up the scope for cooperation across agents. Thus, introducing dynamics into this game theory framework could generate richer strategic behavior and help explain tax rates empirically observed.

7.1 Tax Harmonization

The only path to completely eliminate inefficiencies associated with firm location decisions—while respecting the optimal location condition in (19)—is to impose a uniform effective tax rate across all states. Therefore, the natural counterfactual benchmark is the harmonization of all VAT rates across Brazilian states. To further address inefficiencies arising from heterogeneous cross-sector taxation, counterfactual all tax rates are also chosen to be uniform regardless of sector. I report how aggregate consumption and aggregate state tax revenues (public goods) vary as a function of a uniform country-wide VAT rate. These results are presented in figure 4[7]. It is important to emphasize that all counterfactual exercises approximate agricultural VAT rates to zero in both the baseline and counterfactual scenarios. This assumption reflects the longstanding practice whereby agriculture has benefited from federally mandated VAT exemptions and has contributed only a negligible share of VAT revenues to Brazilian states. Moreover, maintaining a zero VAT rate on agricultural products abstracts from political pressures related to food subsidies, and it allows me to focus on the issue of tax competition.

Figures (4a) and (4b) illustrate the costs associated with the Brazilian fiscal war. Namely, the figures show at different levels of a harmonized tax rate, estimated gains in private income and public goods provision. Figure 5 showcases allocations associated with aggregate (weak) improvements to

[7]To estimate aggregate changes, it is necessary to first calibrate initial local price levels. As an approximation, I normalize $P_k^f = 1$ for every state k in the baseline. In the appendix, I estimate heterogeneous price levels across states and demonstrate that the results are robust to this assumption.



(a) Aggregate private income ($\hat{Y}/\hat{P}$)

(b) Aggregate public goods provided ($\hat{G}$)

Figure 4: Aggregate effects of tax harmonization

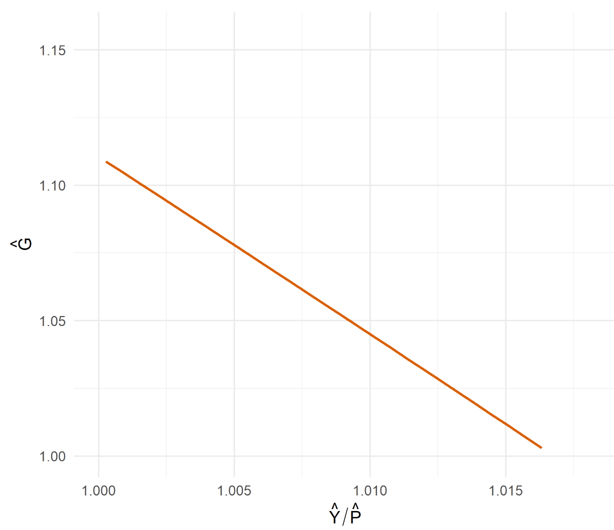


Figure 5: Aggregate improvements of tax harmonization

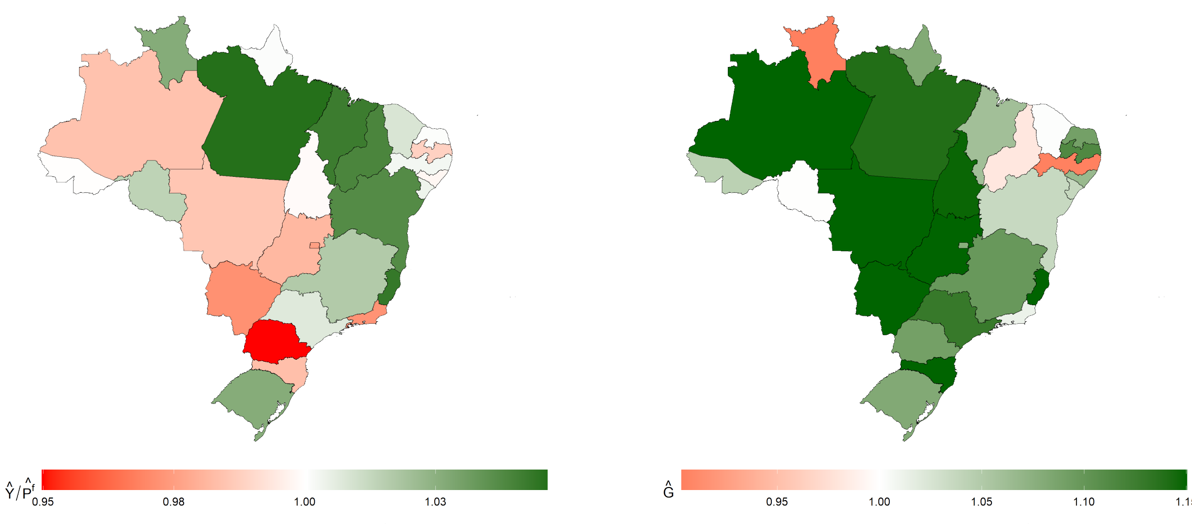
public goods provision and consumption.

In one extreme, one can increase public goods provision by 11 percent at no cost to aggregate consumption by imposing a harmonized tax rate of 11.9. On the other extreme, a harmonized tax rate of 10.6 percent can improve aggregate consumption by 1.6 percent at not cost to aggregate public goods provision.

As a benchmark, I choose to show spatial heterogeneity associated with a uniform VAT rate of 11.9 percent, although the spatial dispersion of gains are very similar across tax rates associated with aggregate improvements.

The effects of tax centralization are heterogeneous across locations. This heterogeneity is illustrated in Figures 6a and 6b. Although most states stand to gain substantially in public goods provision by eliminating the fiscal war, some stand to lose aggregate private income. This result implies that many states succeed in increasing their private income under tax competition.

Similar to the baseline model, some states can attract firms more effectively when allowed to set tax policy independently. Real (private) income losses from tax harmonization are concentrated in states surrounding São Paulo, which pursue particularly aggressive tax-incentive policies (Figure 1). Even at mild changes to these states' effective tax rates, they are able to draw substantial economic activity at a relatively low fiscal cost. The greatest winners from tax harmonization in absolute terms are Brazil's main markets, São Paulo and Minas Gerais. In the decentralized equilibrium, these states maintain relatively high tax levels and lose economic activity to neighboring jurisdictions that offer stronger tax incentives. Under tax harmonization, however, they experience aggregate real private income gains of approximately 1 to 2 percent. In relative terms, more isolated states benefit the most from limitations to tax competition. For instance, Maranhão and Espírito Santo see increases in private income of roughly 4 percent. Intuitively, even under tax competition, these states attract relatively few firms to their jurisdictions. Because they face low benefits under tax competition, they stand to gain the most from removing the distortions associated with firm location decisions.



(a) Private income ($\hat{Y}_\ell$)

(b) Public capital ($\hat{G}_\ell$)

Figure 6: Heterogeneous effects of tax harmonization across states.

7.2 Alternative specifications

Table 5 reports how aggregate outcomes vary across alternative model specifications. I continue to use the tax rate that maximizes aggregate public goods provision subject to no aggregate loses in consumption as a benchmark (11.9 percent) for comparing different model specifications. The results underscore that two model features play a central role in shaping the quantitative impact of tax centralization. First, adopting a spillover parameter of $\beta = 0.05$, as in Fajgelbaum et al. (2019), substantially magnifies the estimated aggregate effects of tax centralization. Intuitively, tax competition tends to constrain public-goods provision. Even mild spillovers from public goods to productivity amplify the adverse consequences of limitations to public goods provision.

Second, profit and rent transfers across regions also influence aggregate outcomes. When interregional profit and rent transfers are eliminated ($\nu_k = 0$), harmonization leads to both stronger public capital gains. Allowing for profit and rent transfers leads to persistent trade imbalances across states, and, therefore, it introduces congestion effects. As firms relocate in response to tax centralization, these transfers persist, dampening the sensitivity of local expenditure to tax policy changes and thereby attenuating the aggregate gains from harmonization.

All other modeling assumptions appear to be quantitatively inconsequential for the aggregate estimates of the costs of tax competition. $\hat{G}$ stands for changes in aggregate public goods provision. $\bar{t}$ stands for the harmonized tax rate that maximizes public revenues subject to weakly increasing aggregate consumption.

Table 5: Different model specifications

Specification	Description	$\hat{G}$	$\bar{t}$
-	Baseline	11%	11.9%
$\beta = 0.05$	With public goods spillovers	87%	20.0%
$\chi_W = 1$	Perfectly rivalrous public goods	12%	11.9%
$\iota_k = 1$	Perfect retention of federal taxation	13%	11.9%
$\theta_u = 0$	No migration	12%	12.0%
$\nu_k = 0$	No profit transfers	25%	13.0%
$\xi_k^T = 0$	No federal transfers	12%	12.0%

8 Conclusion

My findings highlight key features of the "Brazilian fiscal war." First, they demonstrate, both theoretically and empirically, that tax competition is primarily driven by competition for firms in the manufacturing sector. Because firms in this sector exhibit greater mobility, states face stronger incentives to levy lower taxes on manufacturing activity relative to immobile service sectors. Second, my findings highlight the potentially large public goods provision gains of limiting tax competition. In my main specification, it is possible to gain up to 11% in aggregate public goods provision at no cost to aggregate consumption. Third, even though there are aggregate gains to tax harmonization, selected states are predicted to lose as a result of eliminating the fiscal war.

The findings of this paper have several policy implications. First, I demonstrate the potential gains in aggregate tax revenue and public goods provision from limiting governments' ability to engage in tax competition. Second, the results suggest that tax competition is driven primarily by the manufacturing sector. Therefore, tax harmonization is likely to have a disproportionately larger impact in this sector.

Finally, gains from the elimination of tax competition are heterogeneous in space. Some states lose substantial production and consumption capacity if tax competition is limited. These findings underscore the need to design compensatory mechanisms for certain locations when restricting tax competition. Compensating losing states is relevant not only for attenuating the negative impact of tax harmonization in certain locations, but it is especially relevant for effectively implementing limitations to tax competition when adherence to tax limiting programs is voluntary. Targeted transfers or other forms of compensation can offset the associated welfare losses and incentivize states to adhere to measures that will limit the extent of tax competition.

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A Appendix

Institutional details

ORIGIN \ DESTINATION	AC	AL	AM	AP	BA	CE	DF	ES	GO	MA	MT	MS	MG	PA	PB	PR	PE	PI	RN	RS	RJ	RO	RR	SC	SP	SE	TO
AC	19	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
AL	12	20	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
AM	12	12	20	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
AP	12	12	12	18	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
BA	12	12	12	12	20.5	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
CE	12	12	12	12	12	20	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
DF	12	12	12	12	12	12	20	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
ES	12	12	12	12	12	12	12	17	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
GO	12	12	12	12	12	12	12	12	19	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
MA	12	12	12	12	12	12	12	12	12	22	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
MT	12	12	12	12	12	12	12	12	12	12	17	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
MS	12	12	12	12	12	12	12	12	12	12	12	17	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
MG	7	7	7	7	7	7	7	7	7	7	7	7	18	7	7	12	7	7	7	12	12	7	7	12	12	7	7
PA	12	12	12	12	12	12	12	12	12	12	12	12	12	19	12	12	12	12	12	12	12	12	12	12	12	12	12
PB	12	12	12	12	12	12	12	12	12	12	12	12	12	12	20	12	12	12	12	12	12	12	12	12	12	12	12
PR	7	7	7	7	7	7	7	7	7	7	7	7	18	7	7	19.5	7	7	7	12	12	7	7	12	12	7	7
PE	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	20.5	12	12	12	12	12	12	12	12	12	12
PI	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	21	12	12	12	12	12	12	12	12	12
RN	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	18	12	12	12	12	12	12	12	12
RS	7	7	7	7	7	7	7	7	7	7	7	7	12	7	7	12	7	7	7	17	12	7	7	12	12	7	7
RJ	7	7	7	7	7	7	7	7	7	7	7	7	12	7	7	12	7	7	7	12	22	7	7	12	12	7	7
RO	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	19.5	12	12	12	12	12
RR	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	20	12	12	12	12
SC	7	7	7	7	7	7	7	7	7	7	7	7	12	7	7	12	7	7	7	12	12	7	7	17	12	7	7
SP	7	7	7	7	7	7	7	7	7	7	7	7	12	7	7	12	7	7	7	12	12	7	7	12	18	7	7
SE	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	20	12
TO	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	20

Figure 7: ICMS statutory schedule in 2025.

Statutory ICMS rates depend on origin and destination. While the effective rate for a product can be administratively complex, a practical approximation is to apply the default statutory rates in Figure (7).

States use two broad instruments to grant incentives: *tax credits* and *rate reductions*. Credits, although operationally intricate, aggregate cleanly: the fiscal cost equals the sum of reported credits (from the *Escrituração Fiscal Digital*, EFD). Rate reductions are conceptually simpler but harder to aggregate. In principle, a lower upstream rate could be partly offset downstream due to VAT chain properties. In practice, Brazilian states rarely design reductions to generate such cascading;

reductions typically apply to final goods or terminal supply-chain stages.

For instance, in São Paulo large exemptions have targeted retail, wholesale, transportation, staple foods, machinery, and automotive retail/maintenance. Reductions on final goods propagate uniformly downstream; reductions to retailers/wholesalers face no downstream payer. Thus, aggregating forgone revenues usually requires no major adjustments, though state authorities account for rare responsibility transfers when they occur.

A.1 Baseline model

The first-order condition (FOC) for the local government's problem is

$$\left[\frac{\partial U_\ell}{\partial G_\ell}\left(\frac{\partial G_\ell}{\partial t^y_\ell}+\frac{\partial G_\ell}{\partial Y_\ell}\frac{dY_\ell}{dt^y_\ell}\right)+\frac{\partial U_\ell}{\partial C_\ell}\left(\frac{\partial C_\ell}{\partial t^y_\ell}+\frac{\partial C_\ell}{\partial Y_\ell}\frac{dY_\ell}{dt^y_\ell}\right)\right]=0. \tag{43}$$

Plugging in functional forms and simplifying yields:

$$\frac{\alpha^\gamma}{L_\ell^{\chi_W(1-\gamma)+\gamma}}\left(\frac{1-t^y_\ell}{t^y_\ell}\right)^\gamma\left[(1-\gamma)-\gamma\frac{t^y_\ell}{1-t^y_\ell}+\varepsilon_{Y_\ell,t^y_\ell}\right]=0 \tag{44}$$

Labor-market clearing implies wages w_ℓ as a function of taxes, productivity, public goods, and labor supply:

$$w_\ell=\frac{\alpha(1-t^y_\ell)(\zeta_\ell Z_\ell)G^\beta_\ell L^\alpha_\ell}{L_\ell}=\alpha(1-t^y_\ell)\frac{Y_\ell}{L_\ell}. \tag{45}$$

If governments maximize local profits only the FOC simplifies to:

$$\underbrace{\frac{\beta}{1-\beta}}_{\text{MB: multiplier effect}}=\underbrace{\frac{t^y_\ell}{1-t^y_\ell}+\frac{1}{1-\beta}\left(\frac{1-(\alpha+\frac{1}{\theta})}{\alpha+\frac{1}{\theta}-\beta}\right)(1-M_\ell)\left(\frac{t^y_\ell-\beta}{1-t^y_\ell}\right)}_{\text{MC: appropriation + prod./relocation}}. \tag{46}$$

If governments maximize local per capita utility, the FOC simplifies to:

$$\underbrace{\underbrace{(1-\gamma)}_{\substack{\text{Direct utility}\\ \text{effect}}}+\underbrace{\frac{\beta}{1-\beta}}_{\substack{\text{Multiplier}\\ \text{effect}}}}_{\text{MB}}=\underbrace{\underbrace{\gamma\frac{t^y_\ell}{1-t^y_\ell}}_{\substack{\text{Consumption appro-}\\ \text{priation effect}}}+\underbrace{\frac{1}{1-\beta}\left(\frac{1-(\alpha+\frac{1}{\theta})}{\alpha+\frac{1}{\theta}-\beta}\right)(1-M_\ell)\left(\frac{t^y_\ell-\beta}{(1-t^y_\ell)}\right)}_{\text{Firm production and relocation effect}}}_{\text{MC}} \tag{47}$$

Note that the second derivative of the RHS is:

$$\frac{1-(\alpha+\frac{1}{\theta})}{\frac{1}{\theta}+\alpha-\beta}\frac{1}{(1-t_\ell^y)^2}+\frac{\gamma}{(1-t_\ell^y)^2}(1-M_\ell)+\frac{\gamma t_\ell^y}{1-t_\ell^y}\frac{M_\ell}{t_\ell^y}\left(\frac{1}{1-t_\ell^y}\right)(1-M_\ell)\left(\frac{t_\ell^y-\beta}{\frac{1}{\theta}+\alpha-\beta}\right) \tag{48}$$

Derivations of Special Cases

I present special cases to further illustrate the dynamics of tax competition under the model proposed.

1. Symmetry. If states are symmetric ($\zeta_\ell L_\ell^\alpha$ are the same for all ℓ) it must be that in equilibrium:

$$t_\ell^y=\beta+\frac{(1-\gamma)(\frac{1}{\theta}+\alpha-\beta)}{1-\frac{1}{L}\left(1-\alpha-\frac{1}{\theta}\right)\left(\frac{1}{1-\beta}\right)} \qquad \forall \ell\in L \tag{49}$$

2. One single state. If there is a single state setting tax rates, it holds power analogous to a monopolist. It can be shown that in equilibrium:

$$t_\ell^y=\beta+(1-\gamma)(1-\beta) \quad \forall \ell\in\{1,\dots,L\}. \tag{50}$$

3. Infinite states. As the number of non-trivial ($\zeta_\ell \overline{L}_\ell^\alpha>0$) locations approaches infinity, one can show that in equilibrium, states will set:

$$t_\ell^y=\beta+(1-\gamma)\big(\alpha+\tfrac{1}{\theta}-\beta\big) \quad \forall \ell\in\{1,\dots,L\} \tag{51}$$

The following claims are useful for the subsequent proofs:

(I) The function M_ℓ is increasing in t_ℓ^y for $t_\ell^y<\beta$ and decreasing for $t_\ell^y>\beta$:

$$\frac{dM_\ell}{dt_\ell^y}=M_\ell\big(1-M_\ell\big)\frac{\beta-t_\ell^y}{\big(\frac{1}{\theta}+\alpha-\beta\big)\,t_\ell^y(1-t_\ell^y)}.$$

(II)

$$\frac{d\mathcal{E}_{Y_\ell,t^y_\ell}}{dt^y_\ell} = -\frac{1-(\alpha+\frac{1}{\theta})}{\frac{1}{\theta}+\alpha-\beta}\left[\frac{1-M_\ell}{(1-t^y_\ell)^2} + \frac{M_\ell\big(1-M_\ell\big)\,(\beta-t^y_\ell)^2}{(1-t^y_\ell)^2(1-\beta)\left(\frac{1}{\theta}+\alpha-\beta\right)\,t^y_\ell}\right]. \tag{52}$$

Proofs of Propositions

4. Proof of Proposition 1.

Proof. The proof of existence is short. For finite $\mathcal{L}$, the first order conditions in (47) are continuous functions defined on a closed and bounded convex subset of an Euclidean space. Brouwer's fixed-point theorem applies. A solution must exist.

I move on to prove uniqueness. Suppose, for contradiction, that there are 2 equilibria. Without loss of generality, there exists a location ℓ for which $t^1_\ell < t^2_\ell$. Notice that across equilibria, it must be that any 2 tax rates must satisfy:

$$\gamma\frac{t^2_\ell}{1-t^2_\ell} + \frac{1}{1-\beta}\left(\frac{1-(\alpha+\frac{1}{\theta})}{\alpha+\frac{1}{\theta}-\beta}\right)(1-M^2_\ell)\left(\frac{t^2_\ell-\beta}{1-t^2_\ell}\right)$$
$$= \gamma\frac{t^1_\ell}{1-t^1_\ell} + \frac{1}{1-\beta}\left(\frac{1-(\alpha+\frac{1}{\theta})}{\alpha+\frac{1}{\theta}-\beta}\right)(1-M^1_\ell)\left(\frac{t^1_\ell-\beta}{1-t^1_\ell}\right)$$

Therefore,

$$\left(1-M^2_\ell\right)\left(\frac{t^2_\ell-\beta}{1-t^2_\ell}\right) < \left(1-M^1_\ell\right)\left(\frac{t^1_\ell-\beta}{1-t^1_\ell}\right)$$
$$\Rightarrow M^2_k > M^1_k$$

In equilibrium, it must be that any tax rate $t_k \geq \beta$. Therefore, it must be that:

$$\sum_j \left([(1-t^2_j)]^{1-\beta}(t^2_j)^\beta\zeta_j L^\alpha_j\right)^{\frac{1}{\frac{1}{\theta}+\alpha-\beta}} > \sum_j \left([(1-t^1_j)]^{1-\beta}(t^1_j)^\beta\zeta_j L^\alpha_j\right)^{\frac{1}{\frac{1}{\theta}+\alpha-\beta}}$$

Each element of the sum is a decreasing function of t_j, for tax rates greater than β. However, it must then be that there exists a location k such that $t_k^2 < t_k^1$. But then in k:

$$(1 - M_k^2)\left(\frac{t_k^2 - \beta}{1 - t_k^2}\right) > (1 - M_k^1)\left(\frac{t_k^1 - \beta}{1 - t_k^1}\right)$$

Which implies:

$$\sum_j \left([(1 - t_j^2)]^{1-\beta}(t_j^2)^{\beta}\zeta_j L_j^{\alpha}\right)^{\frac{1}{\frac{1}{\theta}+\alpha-\beta}} < \sum_j \left([(1 - t_j^1)]^{1-\beta}(t_j^1)^{\beta}\zeta_j L_j^{\alpha}\right)^{\frac{1}{\frac{1}{\theta}+\alpha-\beta}}$$

Contradiction. It must be that there exists at most 1 equilibrium.

□

5. Proof of Proposition 2.

Proof. The following must hold given 47 for any two arbitrary t_ℓ^y, t_j^y.

$$\frac{t_\ell^y - \beta}{t_j^y - \beta} = \frac{1 + \dfrac{1 - (\alpha + \frac{1}{\theta})}{\alpha + \frac{1}{\theta} - \beta}(1 - M_j)}{1 + \dfrac{1 - (\alpha + \frac{1}{\theta})}{\alpha + \frac{1}{\theta} - \beta}(1 - M_\ell)}$$

If $t_\ell^y > t_j^y$, then $M_\ell < M_j$. Then:

$$\left([(1 - t_\ell^y)]^{1-\beta}(t_\ell^y)^{\beta}\zeta_\ell L_\ell^{\alpha}\right)^{\frac{1}{\frac{1}{\theta}+\alpha-\beta}} < \left([(1 - t_j^y)]^{1-\beta}(t_j^y)^{\beta}\zeta_j L_j^{\alpha}\right)^{\frac{1}{\frac{1}{\theta}+\alpha-\beta}}$$

Which implies:

$$\frac{\left([(1 - t_\ell^y)]^{1-\beta}(t_\ell^y)^{\beta}\right)^{\frac{1}{\frac{1}{\theta}+\alpha-\beta}}}{\left([(1 - t_j^y)]^{1-\beta}(t_j^y)^{\beta}\right)^{\frac{1}{\frac{1}{\theta}+\alpha-\beta}}} < \frac{\left(\zeta_j L_j^{\alpha}\right)^{\frac{1}{\frac{1}{\theta}+\alpha-\beta}}}{\left(\zeta_\ell L_\ell^{\alpha}\right)^{\frac{1}{\frac{1}{\theta}+\alpha-\beta}}}$$

Finally, in equilibrium any $t_k^y > \beta$, and $[(1 - t_\ell^y)]^{1-\beta}(t_\ell^y)^{\beta}$ is decreasing in $t_\ell > \beta$.

Therefore, if $\zeta_j L_j > \zeta_\ell L_\ell$ it must be that $t_\ell^y < t_j^y$. Conversely, if $t_\ell^y < t_j^y$ it must be that $\zeta_j L_j > \zeta_\ell L_\ell$. □

6. Proof of Proposition 3.

Proof. First, I start by showing a decentralized tax system equilibrium cannot be Pareto efficient. Consider a Pareto efficient allocation with non-zero weights ($\lambda_\ell > 0$). FOC's are:

$$\lambda_\ell \left[(1-\gamma)\frac{U_\ell}{t_\ell^y}\left(1+\mathcal{E}_{Y_\ell,t_\ell^y}\right) + \gamma\frac{U_\ell}{1-t_\ell^y}\left(-1+\frac{1-t_\ell^y}{t_\ell^y}\mathcal{E}_{Y_\ell,t_\ell^y}\right)\right] + \sum_{k\neq\ell}\lambda_k\frac{U_k}{t_\ell^y}\left(\frac{1}{1-\beta}\right)\left(\frac{1-(\alpha+\frac{1}{\theta})}{1-t_\ell^y}\right)M_\ell \;=\; 0$$

Which can be rearranged to:

$$(1-\gamma)+\mathcal{E}_{Y_\ell,t_\ell^y} - \gamma\frac{t_\ell^y}{1-t_\ell^y} = -\sum_{k\neq\ell}\frac{\lambda_k}{\lambda_\ell}\frac{U_k}{U_\ell}\left(\frac{1}{1-\beta}\right)\left(\frac{1-(\alpha+\frac{1}{\theta})}{1-t_\ell^y}\right)M_\ell$$

Which can only be equivalent to the FOCs of the decentralized equilibrium in case the right-hand side equals zero ($\mathcal{L}=1$).

Now consider a decentralized equilibrium's tax rate level $\{t_k^{dec}\}_k$. Denote $\{t_k^P\}_k$ as a Pareto efficient allocation that dominates $\{t_k^{dec}\}_k$. The two first order conditions associated with these allocations are:

$$(1-\gamma)+\mathcal{E}_{Y_\ell,t_\ell^y} - \gamma\frac{t_\ell^y}{1-t_\ell^y} = 0$$

$$(1-\gamma)+\mathcal{E}_{Y_\ell,t_\ell^y} - \gamma\frac{t_\ell^y}{1-t_\ell^y} = -\sum_{k\neq\ell}\frac{\lambda_k}{\lambda_\ell}\frac{U_k}{U_\ell}\left(\frac{1}{1-\beta}\right)\left(\frac{1-(\alpha+\frac{1}{\theta})}{1-t_\ell^y}\right)M_\ell$$

The left-hand side of both equations is decreasing in t_ℓ^y as $\mathcal{E}_{Y_\ell,t_\ell^y}$ is decreasing in t_ℓ^y (Equation 52). It must, therefore, be that $t_k^P > t_k^{dec}$. Since the argument was made for an arbitrary k, it must hold for all locations. By setting $\varepsilon_k = t_k^P - t_k^{dec}\}_k$, it must be possible to achieve a Pareto dominant allocation.

□

Household side

Under the Fréchet assumption, the equilibrium mass of households in ℓ is

$$L_\ell = \left(\frac{\zeta_\ell \, u_\ell}{\left(\sum_k [\zeta_k u_k]^{\theta^W} \right)^{1/\theta^W}} \right)^{\theta^W} . \tag{53}$$

Firm side

Baseline profits (origin o, destination d, sector s) are

$$\pi^s_{od}(i) = (1 - t^\pi_o)\big\{(1 - t^s_{od})\big[p^s_{od}(i) q^s_{od}(i) - \tau_{od} P^{I,s}_o i_{od}(i)\big] - \tau_{od} r_o h_o(i) - \tau_{od} w_o n_{od}(i)\big\} - w_d F_d. \tag{54}$$

Equivalently, with marginal cost MC^s_{od} and productivity draw $\tilde{z}_{od}(i)$,

$$\pi^s_{od}(i) = (1 - t^\pi_o) \left\{ (1 - t^s_{od}) p^s_{od}(i) q_{od}(i) - \frac{\tau_{od} MC^s_{od}}{\tilde{z}_{od}(i)} \, q_{od}(i) \right\} - w_d F_d. \tag{55}$$

Under monopolistic competition (constant markup $\sigma^s/(\sigma^s - 1)$),

$$\pi^s_{od}(i) = \frac{1}{\sigma^s} (1 - t^\pi_o)(1 - t^s_{od}) \, p^s_{od}(i) q_{od}(i) - w_d F_d. \tag{56}$$

Given sectoral expenditure X^s_d at d,

$$\pi^s_{od}(i) = \frac{1}{\sigma^s} (1 - t^\pi_o)(1 - t^s_{od}) \left(\frac{(1 - t^s_{od}) \, \tilde{z}_{od}(i)}{\tau_{od} \, c^s_o} \right)^{\sigma^s - 1} \left(\frac{P^s_d}{\sigma^s/(\sigma^s - 1)} \right)^{\sigma^s - 1} X^s_d - w_d F_d. \tag{57}$$

Aggregation

Let $\{z_k\}$ be multivariate Pareto with $(\zeta^F_k, \rho^s, \theta^s)$. Then

$$\{z_k^{\sigma^s - 1} \kappa_{kd}\}_k \sim \text{MVP}\left(\zeta^F_k \, \kappa_{kd}^{\frac{\theta^s}{\sigma^s - 1}}, \, \rho^s, \, \frac{\theta^s}{\sigma^s - 1} \right). \tag{58}$$

By Arkolakis et al. (2018), the maximum is univariate Pareto:

$$\max_k \{z_k^{\sigma^s - 1} \kappa_{kd}\} \sim \text{Pareto}\left(\left(\sum_k [\zeta^F_k]^{\frac{1}{1-\rho^s}} \, \kappa_{kd}^{\frac{1}{1-\rho^s} \frac{\theta^s}{\sigma^s - 1}} \right)^{\frac{1-\rho^s}{\theta^s}}, \, \rho^s, \, \frac{\theta^s}{\sigma^s - 1} \right). \tag{59}$$

If fixed costs bind, the mass of entrants and conditional expectation are

$$M_{od} := \Pr\Big\{[z_o^s(i)]^{\sigma^s-1}\kappa_{od}^s \geq \underline{C} \;\cap\; \arg\max_k [z_k^s(i)]^{\sigma^s-1}\kappa_{kd}^s = o\Big\} = \underline{C}^{-\frac{\theta^F}{\sigma^s-1}}\psi_{od}\,\Upsilon_d, \tag{60}$$

$$Z'_{od} := \mathbb{E}\big([z_o(i)]^{\sigma^s-1}\kappa_{od}^s \,\big|\, \text{entry \& locate in } o\big) = \frac{\theta^F}{\theta^F-(\sigma^s-1)}\,\underline{C}\,M_{od}. \tag{61}$$

Where

$$\Upsilon_d = \left[\sum_k [\zeta_k^F]^{\frac{1}{1-\rho^s}}\,[(1-t_k^\pi)(1-t_{kd}^s)]^{\frac{\theta^F}{(1-\rho^F)(\sigma^s-1)}}\left(\frac{(1-t_{kd}^s)^{\phi^s}\left(\frac{G_k}{M_k^{XF}}\right)^{\beta^s}}{c_k^s\tau_{kd}}\right)^{\frac{\theta^F}{1-\rho^F}}\right]^{1-\rho^F}, \tag{62}$$

$$\underline{C}_d = \left(\frac{\sigma^s w_d F_d}{X_d^s}\right)\left(\frac{\frac{\sigma^s}{\sigma^s-1}}{P_d^s}\right)^{\sigma^s-1}. \tag{63}$$

Price indices satisfy

$$P_d^s = \left[\sum_k\int_i\left(\frac{\sigma^s}{\sigma^s-1}\frac{1}{(1-t_{kd}^s)}\frac{\tau_{kd}c_k^s}{\tilde{z}_k(i)}\right)^{1-\sigma^s}\right]^{\frac{1}{1-\sigma^s}} = \frac{\sigma^s}{\sigma^s-1}\left[\sum_k\frac{Z'_{kd}}{(1-t_k^\pi)(1-t_{kd}^s)}\right]^{\frac{1}{1-\sigma^s}}. \tag{64}$$

Using (61) yields

$$P_d^s = \tilde{\sigma}^s\left[\frac{\theta^s}{\theta^s-(\sigma^s-1)}\,\Upsilon_d\left(\frac{\sigma^s w_d F_d}{X_d^s}\right)^{1-\frac{\theta^s}{\sigma^s-1}}\sum_k\frac{\psi_{kd}}{(1-t_{kd}^s)(1-t_k^\pi)}\right]^{-\frac{1}{\theta^s}}, \quad \tilde{\sigma}^s := \frac{\sigma^s}{\sigma^s-1}. \tag{65}$$

Gravity for expenditure flows:

$$X_{od}^s = (P_d^s)^{\sigma^s-1}X_d^s\,(\tilde{\sigma}^s)^{1-\sigma^s}\frac{Z'_{od}}{(1-t_{od}^s)(1-t_o^\pi)}. \tag{66}$$

Hence trade shares $\lambda_{od}^s := X_{od}^s/X_d^s$ are

$$\lambda_{od}^s = \frac{\frac{Z'_{od}}{(1-t_{od}^s)(1-t_o^\pi)}}{\sum_k\frac{Z'_{kd}}{(1-t_{kd}^s)(1-t_k^\pi)}} = \frac{\frac{\psi_{od}}{(1-t_{od}^s)(1-t_o^\pi)}}{\sum_k\frac{\psi_{kd}}{(1-t_{kd}^s)(1-t_k^\pi)}}. \tag{67}$$

In extensive form,

$$\lambda_{od}^{s} = \frac{[\zeta_o^F]^{\frac{1}{1-\rho^s}} \left[(1-t_o^{\pi})(1-t_{od}^s)\right]^{\frac{\theta^F}{(1-\rho^F)(\sigma^s-1)}-1} \left(\frac{(1-t_{od}^s)\left(\frac{G_o}{M_o^{XF}}\right)^{\beta^s}}{c_o^s \tau_{od}} \right)^{\frac{\theta^F}{1-\rho^F}}}{\sum_k [\zeta_k^F]^{\frac{1}{1-\rho^s}} \left[(1-t_k^{\pi})(1-t_{kd}^s)\right]^{\frac{\theta^F}{(1-\rho^F)(\sigma^s-1)}-1} \left(\frac{(1-t_{kd}^s)\left(\frac{G_k}{M_k^{XF}}\right)^{\beta^s}}{c_k^s \tau_{kd}} \right)^{\frac{\theta^F}{1-\rho^F}}}. \tag{68}$$

Finally, the compact price index used later is

$$P_d^s = \tilde{\sigma}^s \left[\frac{\theta^s}{\theta^s - (\sigma^s - 1)} \Upsilon_d \right]^{-\frac{1}{\theta^s}} \left(\frac{\sigma^s w_d F_d}{X_d^s} \right)^{-\frac{1}{\theta^s} + \frac{1}{\sigma^s - 1}} \left[\sum_k \frac{\psi_{kd}}{(1-t_{kd}^s)(1-t_k^{\pi})} \right]^{-\frac{1}{\theta^s}}. \tag{69}$$

Hat algebra

Price-index hats follow

$$\hat{P}_d^s = \left(\frac{\hat{w}_d}{\hat{X}_d^s} \right)^{-\frac{1}{\theta^s} + \frac{\theta^s}{\sigma^s - 1}} \left[\frac{\sum_k (1-t_{kd}^s)'(1-t_k^{\pi})'[\lambda_{kd}^s]'}{\sum_k (1-t_{kd}^s)(1-t_k^{\pi})\lambda_{kd}^s} \right]^{\frac{1}{\theta^s}} \left(\sum_k (1-t_k^{\pi})(1-t_{kd}^s)\lambda_{kd}^s \, \Xi_{kd} \right)^{-\frac{1-\rho^s}{\theta^s}}, \tag{70}$$

$$\Xi_{kd} := \left(\frac{(\widehat{1-t_k^{\pi}})^{\frac{1}{\sigma^s-1}} (\widehat{1-t_{kd}^s})^{\frac{1}{\sigma^s-1}+\phi^s} (\hat{G}_k/\hat{M}_k^{XW})^{\beta^s}}{[\hat{w}_k^{1-\delta^s} \hat{r}_k^{\delta^s}]^{\phi^s} \left[\prod_u (\hat{P}_k^u)^{\alpha_k^{u,s}} \right]^{1-\phi^s}} \right)^{\frac{\theta^s}{1-\rho^s}}. \tag{71}$$

Labor allocation (hats) is

$$\hat{L}_d = \frac{\left[\left(\frac{\hat{G}_d}{\hat{L}_d^{XW}} \right)^{\gamma_d} \left(\frac{(\widehat{1-t_d^y})\hat{w}_d}{\hat{P}_d^C} \right)^{1-\gamma_d} \right]^{\theta^u}}{\sum_k L_k \left[\left(\frac{\hat{G}_k}{\hat{L}_k^{XW}} \right)^{\gamma_k} \left(\frac{(\widehat{1-t_k^y})\hat{w}_k}{\hat{P}_k^C} \right)^{1-\gamma_k} \right]^{\theta^u}}. \tag{72}$$

Gravity equation and calibration procedure

Value-added ϕ^S and labor share of value-added payment δ^S parameters can be computed as:

$$\phi^S = 1 - \left(\frac{1}{1 - \frac{1}{\sigma^S}} \right) \left[1 - \frac{\sum_j X_{\ell j}^S - P_\ell^S I_\ell^S}{\sum_j X_{\ell j}^S} \right] \tag{73}$$

$$\delta^S = \frac{1}{1 + \frac{w_\ell N_\ell^S}{r_\ell H_\ell^S}} = 1 - \left(1 - \frac{w_\ell N_\ell^T}{\sum_j (1 - t_{\ell j}^S) X_{\ell j}^S}\right) \left(\frac{1}{1 - \frac{1}{\sigma_S}}\right) \left(\frac{1}{\phi_S}\right) \tag{74}$$

Note that under symmetry, iceberg costs may also be retrieved. First note that:

$$\frac{X_{\ell\ell}^T}{X_{j\ell}^T} \times \frac{X_{jj}^T}{X_{\ell j}^T} = \left(\frac{\tau_{\ell j}^T \tau_{j\ell}^T}{\tau_{\ell\ell}^T \tau_{jj}^T}\right)^{\frac{\theta^s}{1-\rho^s}} \left[\frac{(1 - t_{\ell\ell}^T)(1 - t_{jj}^T)}{(1 - t_{j\ell}^T)(1 - t_{\ell j}^T)}\right]^{\frac{\theta^s}{1-\rho^s}\left[\frac{\sigma^T}{\sigma^T-1} - (1-\phi^T)\right] - 1} \tag{75}$$

Which can be rearranged:

$$\tau_{\ell j}^T = \left(\frac{X_{\ell\ell}^T}{X_{j\ell}^T} \times \frac{X_{jj}^T}{X_{\ell j}^T}\right)^{\frac{1}{2}\frac{1-\rho^F}{\theta}} \left[\frac{(1 - t_{\ell\ell}^T)(1 - t_{jj}^T)}{(1 - t_{\ell j}^T)(1 - t_{j\ell}^T)}\right]^{\frac{1}{2}\frac{1-\rho^F}{\theta} - \frac{1}{2}\left(\frac{\sigma}{\sigma-1} - (1-\phi^T)\right)} \tag{76}$$

Other transfer and network parameters are pinned down as follows. $\{\xi_\ell\}$ targets empirical transfer rules from the federal government and can be calibrated using empirical transfers.

$$\xi_d^T = \frac{T_d^{\text{FED}\to d}}{\sum_k T_k^{\text{FED}}} \tag{77}$$

$\{\iota_\ell\}$ targets deviations from implied tax collection to effective tax collection across states:

$$\iota_\ell = \frac{T_d^{\text{FED,effective}}}{T_d^{\text{FED,implied}}} \tag{78}$$

Where $T_d^{\text{FED,effective}}$ is the observed tax collection in a state d, while $T_d^{\text{FED,implied}}$ is the implied tax revenue collected in d given the statutory federal tax rates $\{t^{\text{VAT,FED}}, t^y, t^\pi\}$

$\{\nu_\ell\}$ targets production-expenditure imbalances after accounting for governmental transfers, which can be rearranged to calibrate ν_ℓ:

$$\nu_d = \frac{\Delta_d + \left(\tilde{\Pi}_d + r_d \overline{H}_d\right) - \left[\left(s\xi_d^T + (1-s)\xi_d^D\right) \sum_j T_j^{\text{FED}} - T_d^{\text{FED}}\right] - \left[\sum_s \sum_k d_{ks}^s \, TR_k^{s,\text{ST}} - \sum_s \sum_k t_{dk}^{\text{VAT,st}} \lambda_{dk}^s X_k^s \left[1 - (1-\phi^s)\left(1 - \frac{1}{\sigma^s}\right)\right]\right]}{\sum_j \left(\tilde{\Pi}_j + r_j \overline{H}_j\right)} \tag{79}$$

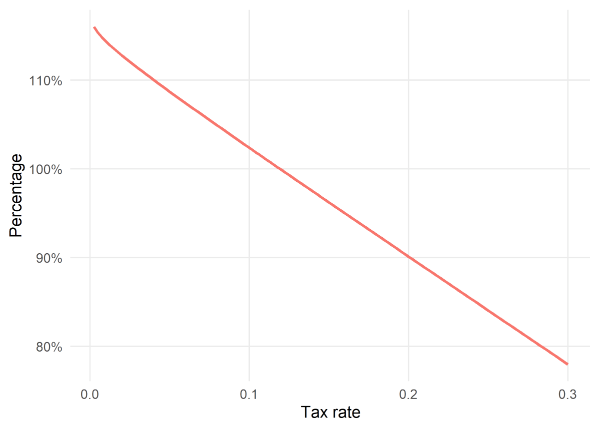
Finally, $\{\alpha_d^{s,u}\}$ pins down the network induced by input–output loops. I can calibrate these parameters by observing expenditure patterns in intermediate goods across sectors:

$$\alpha_d^{s,u} = \frac{P_d^{I,s,u} I_d^{s,u}}{\sum_k P_d^{I,k,u} I_d^{k,u}} \tag{80}$$

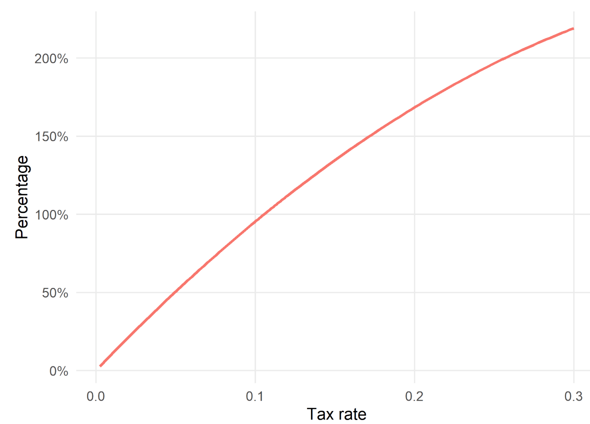
if $P_d^{I,s,u} I_d^{s,u}$ denotes expenditure in intermediate goods in sector s and location d by sector u.

Counterfactual: Tax Harmonization

As a robustness exercise, I allow for heterogeneous baseline price levels across states rather than imposing $P_k^f = 1$. State-level prices are estimated directly from expenditure and revenue data. Figure (8) illustrates that the main qualitative results are robust to this adjustment.



(a) Aggregate private income (estimated prices)



(b) Aggregate state government expenditure (estimated prices)

Figure 8: Macroeconomic effects of VAT harmonization with estimated baseline price levels.

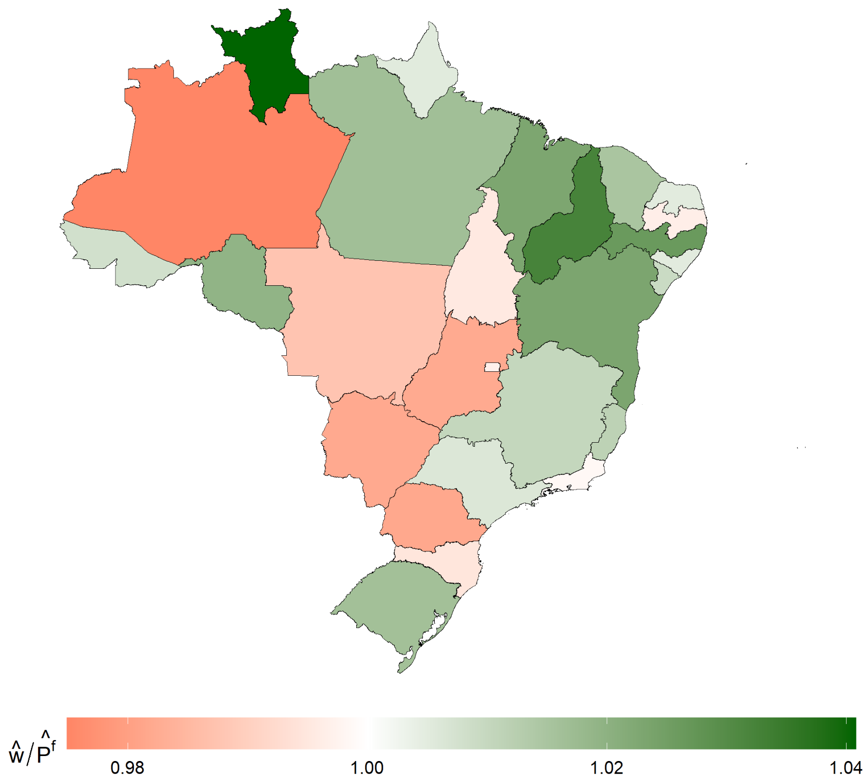


Figure 9: Map of $\hat{w}/\hat{P}^f$ by state.

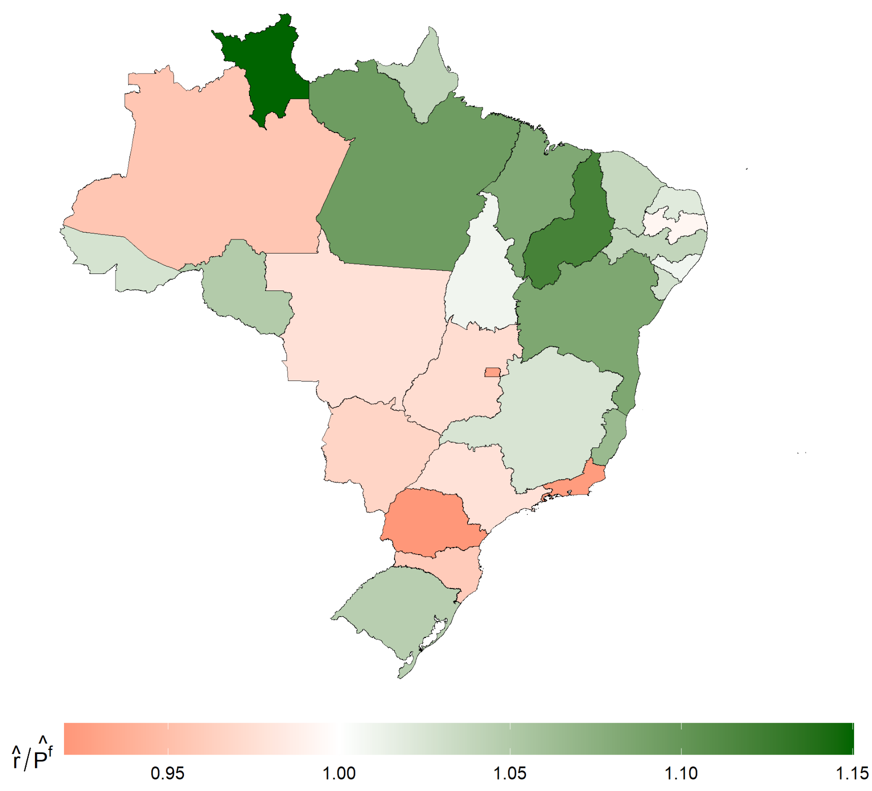


Figure 10: Map of $\hat{r}/\hat{P}^f$ by state.

Fixed point algorithm

I denote M_*, matrices that lead to vectorized versions of equations presented in the main text.

The fixed point algorithm relies, in part, on initial levels of some expenditure-related variables so that relative changes can be computed. To obtain such initial levels, I rely solely on expenditure data stemming from regional accounting data. First, note that one can rewrite equation (36) as:

$$X = [I - M_1]^{-1}\alpha^F Y \tag{81}$$

Furthermore, given X, one must consider equations (37), (38), net profits , gross profits, equation (30), and (33) can be expressed as, respectively:

$$wN = M_4X + M_5X \tag{82}$$

$$rH = M_2X \tag{83}$$

$$\widetilde{\Pi} = M_3X \tag{84}$$

$$\Pi = M_6X \tag{85}$$

$$T^{\text{FED}} = \Big[t^y(M_4X + M_5X)\Big] + \Big[t^\pi M_6X\Big] + [M_7X] \tag{86}$$

$$PG = DM_8X + (s\xi^T)\iota\left\{\Big[t^y(M_4X + M_5X)\Big] + \Big[t^\pi M_6X\Big] + [M_7X]\right\} \tag{87}$$

Moreover, one can express equation (39) as:

$$[I - \Lambda]X = [\nu - I][M_2 + (1 - t^\pi)M_3]X + \widetilde{\xi}\left\{t^y(M_4 + M_5) + t^\pi M_6 + M_7\right\}X + [DM_9 - M_{10}] \tag{88}$$

Which can be rearranged using (81) as:

$$[(I-\Lambda) - [\nu - I][M_2 + (1-t^\pi)M_3] - \widetilde{\xi}[t^y(M_4+M_5) + t^\pi M_6 + M_7] - (DM_9 - M_{10})][I - M_1]^{-1}\alpha^F Y = 0 \tag{89}$$

Where $\widetilde{\xi} = [(s\xi^T) + ((1-s)\xi^D) - I]\iota$. Finally, equations (34) and (35) connect income to wages.

$$Y^{pub} = DM_8X + (s\xi^T + (1-s)\xi^D)\iota\left\{\left[t^y(M_4X + M_5X)\right] + \left[t^\pi M_6X\right] + [M_7X]\right\} \tag{90}$$

$$Y^{priv} = \nu\left[rH + \widetilde{\Pi}\right] + [(1-t^y)wN] \tag{91}$$

Another useful formulation of equation (81) is X in terms of wN and rH

$$X' = \left[I - M_1 - \nu M_3 - DM_8 - (s\xi^T + (1-s)\xi^D)\iota(t^\pi M_6 + M_7) - (1-\iota)\left(t^\pi M_6 + M_7\right)\right]^{-1}$$
$$\times\left[\nu rH + (1-t^y)wN + (s\xi^T + (1-s)\xi^D)\iota\left[t^y w'N'\right] + (1-\iota)(t^y w'N')\right]. \tag{92}$$

Therefore, to compute an equilibrium in relative changes I use the following procedure:

1. With initial data on expenditure X, compute $\{wN, rH, \widetilde{\Pi}, \Pi, T^{FED}, PG\}$ with equations (81)-(91)
2. Guess change in prices $\hat{P} = \hat{w} = \hat{r} = \hat{L} = \hat{G} = 1$
3. In a fixed point algorithm, from inner to outer loop compute the following:
   (a) In the inner most loop compute X', $\hat{P}$ and $\hat{\lambda}$.
   (b) In the 2nd inner most loop compute $Y^{implied}$ so that equation (89) holds. Adjust r and w (with dampening) with this $Y^{implied}$
   (c) In the 3rd inner most loop, adjust $\hat{G}$ (with dampening) so that equation (87) holds
   (d) Finally, in the outermost loop, adjust $\hat{L}$ (with dampening) so that equation (72) holds

Simulated Method of Moments

For calibrating the parameter $\{\gamma_\ell\}$, I rely on the institutional fact that state governments primarily manipulate tax burdens through the issuance of tax cuts. These tax rate reductions are granted at the firm or sectoral level and, in most cases, apply uniformly across all destination markets [8]. This uniformity reflects constitutional principles that restrict states from differentiating tax treatment based on the buyer's location.

[8] see for example Lei Estadual nº 8.490, de 28 de dezembro de 2018

There exist minor exceptions[9] that permit states to offer an additional 5-10 percent tax incentive specifically for interstate transactions, but these programs apply only to a narrow set of states and firms. Even in such cases, given the interstate ICMS ceiling rate of 12 percent, the implied discrepancy between the estimated and actual effective rates is small: at most about 1.2 percentage points, and only for the affected firms which represent a subset of a state's economy.

To implement the simulated method of moments, I discretize the grid o potential values for taste parameters γ_ℓ, manufacturing tax rates $t^T_{\ell k}$, and service tax rates $t^{NT}_{\ell k}$. For any ℓ, γ_ℓ follows a grid $[0, 0.005, 0.01, ..., 0.995, 1]$. Tax rates are chosen so that intrastate tax rates follow a grid $[0, 0.005, 0.01, ..., 0.345, 0.350]$ and interstate tax rates are proportionally scaled so that the observed tax rate proportions are maintained within every state.

For every state ℓ and fixed value of γ_ℓ, I compute the best response tax rates $t^T_{\ell k}, t^{NT}_{\ell k}$ from the tax rate grid. Finally, I choose from the γ_ℓ grid the value so that equation 42 holds in each state.

[9] see for example lei Nº 17.118, 10/12/2020 from Pernambuco